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AQUATIC BIOTA AND ABIOTA
OF SELECTED STREAMS
ON THUNDER BASIN NATIONAL GRASSLAND
WYOMING



THESIS
AND
REPORT

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OF SELECTED STREAMS
ON THUNDER BASIN NATIONAL GRASSLAND
WYOMING

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ABSTRACT

In light of coal development activities and as little such study has been undertaken in past years, the objective of this investigation has been to continue developing baseline data on the aquatic biota and abiota of streams on the Thunder Basin National Grassland of Wyoming. This report presents the results of the third year of study on the Little Powder River, the second on Antelope Creek (the headwater of the Cheyenne River) and the first such effort on School and Little Thunder Creeks (located in the Cheyenne River drainage).

The study streams are low-gradient, shallow, sluggish habitats characterized by vast fluctuations in flow, temperature, turbidity and dissolved oxygen content. These waters are quite saline and were periodically found to exceed the "threshold concentration" of 0.1 mg/l for zinc.

None of these streams can be considered a viable sport fishery at present, the predominant game species being black bullhead and green sunfish. Non-game species consist primarily of an assemblage of minnow species. Also collected in low numbers were stonecat, largemouth bass and bluegill.

The benthic invertebrate communities are characterized by low to moderate diversity and generally large seasonal variations in abundance. Predominant forms include Chironomid larvae, freshwater snails, shrimp and clams, beetle larvae, oligochaetes and mayfly and damselfly nymphs. Based upon the habitat types sampled and the diversity values found, a tentative classification system is offered for the streams of Thunder Basin.

Water quality data generally corroborated data collected for other ongoing Eastern Powder River Basin studies. These waters can be characterized as moderately mineralized, well-buffered and hard.

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CHAPTER I

INTRODUCTION

Increasing state, regional, and national interest is presently being shown in the development of the sub-bituminous coal deposits underlying northeastern Wyoming. A portion of these deposits lie on or in the near vicinity of Thunder Basin National Grassland, administered by the U.S. Forest Service. At present, land use in this area is based primarily upon agriculture. However, it is anticipated that such use will probably be changing in the future as development of mineral resources proceeds. As this occurs, both the terrestrial and aquatic environments of the area will be affected, either directly or indirectly.

In past years, little definitive study has been directed toward the aquatic communities existing in the ephemeral, intermittent and perennial stream channels which drain Thunder Basin lands. Without such data, the ability of Forest Service personnel to determine and implement suitable management policies for these lands is reduced. Thus, the objective of this study has been to continue to develop such necessary baseline information by inventorying and evaluating the native benthic invertebrate fauna, fish populations and water quality of the Little Powder River, Antelope Creek, School Creek and Little Thunder Creek, as they flow through Thunder Basin National Grassland.

CHAPTER II

METHODS AND MATERIALS

Physical

The four streams investigated during this study were selected by personnel of the U.S. Forest Service and the principal investigators. Criteria applied for study site selection (total of 6 sites) were:

- 1) location within the boundaries of Thunder Basin National Grassland;
- 2) representation of typical habitat for the study stream;
- 3) proximity to coal development activity, either current or planned;
- 4) accessibility.

Baselines were surveyed along one streambank of each study site, with marker stakes being placed at five-foot intervals. These baselines were then used to map the surface area of the stream and also for sample location purposes. Mapping was conducted by measuring the distance from each stake, perpendicular to the baseline, to the stream edge. Survey techniques were also employed to determine the channel slope.

At each sampling time at each site (except during periods of ice-cover), a discharge measurement was made following standard U.S.G.S. procedure, as described by Corbett, 1962. Velocity measurements were taken at one-foot intervals across the channel at the 0.6 depth using a Price current meter.

Drainage basin characteristics of the study streams were measured

from 1:250,000 U.S. Army Map Service topography maps. The drainage area in square miles was determined by planimetric techniques using a Keuffel and Esser Compensating Polar Planimeter, while total stream length, including all perennial, intermittent and ephemeral channels, was measured with a Keuffel and Esser Map Measurer. Drainage density for the basin was then computed by dividing the total stream length (kilometers) by the drainage area (in square km). The Strahler method was used to determine stream order (Chorley, 1969). In this method, unbranched streams are numbered 1, streams with two or more tributaries rated as 1 are numbered 2, streams with two or more tributaries rated as 2 are numbered 3 and so on.

U.S.G.S. streamflow records for the Little Powder River and Antelope Creek (Cheyenne River) were obtained from Water Resources Data for Wyoming, Part 1: Surface Water Records, and Water Resources Data System (WRDS) (Smith, Pelton and Bender, 1976).

Biological

Fisheries

Fish population sampling was conducted at the six study sites on June 23 and 24, 1976. All collections were made using 7.62 m and 15.24 m nylon seines having a depth of 1.22 m and a 4.8 mm mesh size. Electrofishing techniques could not be employed as the turbid water conditions often encountered would have hampered the recovery of stunned fish due to poor visibility. For each fish collected, total length was measured to the nearest 1.0 millimeter and weight was recorded to the nearest 1.0 gram. To avoid misidentification of juvenile forms, primarily of minnow species (Family Cyprinidae),

representative individuals were preserved in 95 percent alcohol and transported to Laramie for verification using the keys developed by Baxter and Simon, 1970.

Fish population estimates were attempted at each site using the DeLury Removal Method (DeLury, 1947 and 1951). This procedure involved the following steps:

1. The study area was blocked off using natural barriers and seines to prevent escapement from or recruitment to the population.
2. Three seine hauls, each covering the entire enclosed area, were made, with the fish from each haul being placed in a separate "live car" (holding pen).
3. Treating each haul separately, all fish were identified, enumerated, measured and weighed.
4. A graph was then constructed using the Y-axis as the catch for each seine haul and the X-axis as the cumulative catch previous to a given seine haul. This is based on the assumption that as the number of seine hauls increases and the cumulative catch increases, the number of fish per haul will decrease.
5. Following this procedure, the data from the three seine hauls at a particular site were plotted and a line was fitted to these points using linear regression. The estimated number of fish at the site was then the point on the X-axis where this line intercepts it.
6. As the surface area and length of each sample site were measured, estimates were then placed on a numbers per hectare

and per stream kilometer basis for sake of comparison. With the weight data collected, standing crop estimates were also placed on a kilogram per hectare and per kilometer basis.

Fish sampling activities during 1976 were severely hampered due to high water levels and heavy growths of aquatic vegetation. For these reasons, standing crop estimates could be made only at Little Powder River Site #1.

To allow additional comparisons to be made of the community structure of the fish populations present, the Shannon Index of Diversity, as described by Odum (1971), Wilhm (1967) and Wilhm and Dorris (1968), was applied to the data from each site. This index, based upon the formula

$$\bar{H} = [-\sum \left[\left(\frac{n_i}{N} \right) \log_{10} \left(\frac{n_i}{N} \right) \right] 3.321928]$$

where $\bar{H}$ = Shannon index of general diversity

n_i = importance value for each species

N = total of importance values

and 3.321928 is a conversion factor for base 10 log to base 2, represents the wealth of individual types of organisms present (i.e., the number of different types and the number of each type present). The conversion factor to base 2 log was incorporated to conform with the index equation presented by the Environmental Protection Agency (1973).

Benthic Invertebrates

Bottom fauna samples were collected at the Little Powder River and Antelope Creek study sites on April 28, 1976, June 23-24, 1976, September 21-23, 1976, and January 19-20, 1977. Little Thunder and School Creek collections were made on the same dates, with the exception of the Spring samples taken on May 13. On each date, six samples were

taken from each site. Random number tables were employed to select sampling locations with one number being selected to determine the baseline marker stake at which the sample would be taken while a second number determined the sampling distance from the stream bank.

Due to the nature of the substrates present, all bottom samples were taken with an Eckman dredge, a spring-operated, jaw type sampler especially designed for use in soft mud, muck and ooze substrates. Each sample encompassed an area of 0.25 square feet (0.023 m^2). Welch, 1948, discusses the use and operation of this sampler in greater detail.

All bottom fauna samples were preserved immediately in 95% alcohol and transported to Laramie. Here, the samples were washed and screened. The detritus remaining in the screen was placed in white enamel pans and, using a 2X magnifying lamp, the invertebrates present were removed ("picked") and preserved in labelled vials.

The benthic invertebrates were identified to the lowest taxonomic level possible using available keys (Pennak, 1953; Walker, 1953; Ward and Whipple, 1959; Usinger, 1973). The number of each taxonomic type present in each sample was then enumerated and the biomass measured to the nearest milligram (mg) using a Mettler analytical balance. Immediately prior to weighing, all organisms were placed on filter paper and dried at room temperature for 24 hours. Thus, all weights were recorded as "air-dried" weights.

To allow comparisons of relative abundance to be made between both study sites and sampling times, bottom fauna data were placed on a numbers per 0.1 square meter and milligrams per 0.1 square meter basis. Also, Shannon Species Diversity Index values ($\bar{H}$) were calculated for

each site at each time using the formula previously listed in this Chapter. This was to facilitate comparisons of benthic community structure on both a numbers and biomass per 0.1 m^2 basis. To do this, $\bar{H}$ values were computed for each individual sample and these were then averaged to obtain the index number for a given study site at a given sampling time. Kruskal-Wallis Rank-Sum test and Mann-Whitney U-Tests, as described by Dixon and Massey, 1969 and Sokal and Rohlf, 1969, were then used to determine if statistically significant differences existed between $\bar{H}$ values for the study sites and sampling times.

Water Quality

Water quality samples were collected during biological testing at each study site, chemically stabilized (where necessary) and transported to Laramie for processing at the Wyoming Department of Agriculture Chemical and Bacteriological Laboratory. All field and laboratory methods for sample handling, preparation and analysis were in compliance with currently recommended methods (APHA, 1975 and EPA, 1974).

Table 1 presents the chemical constituents monitored during the continuing program at the Little Powder River and Antelope Creek sites as well as for this initial effort on Little Thunder and School Creeks. Three general categories of chemical constituents were monitored at each of the stations sampled. These were:

- 1) commonly occurring cations and anions;
- 2) nutrients and organic indicators;
- 3) trace metals and elements.

Chemical balances between cations and anions were determined following analysis. These determinations "typed" each collected sample

TABLE 1
Chemical Constituents

Calcium	Alkalinity	Fluoride
Magnesium	Ammonia	Iron (total
Sodium	Total Kjeldahl Nitrogen	Lead
Potassium	Nitrite	Manganese
Carbonate	Phosphate (PO ₄)	Mercury
Bicarbonate	Suspended Solids	Nickel
Sulfate	Total Dissolved Solids (TDS)	Selenium
Chloride	Total Solids	Silver
Nitrate	Arsenic	Zinc
Fluoride	Barium	Cyanide
Conductance	Boron	MBAS
COD	Cadmium	Phenol
pH	Copper	Oil and Grease
Turbidity	Chromium (hex)	Sulfides
Hardness		

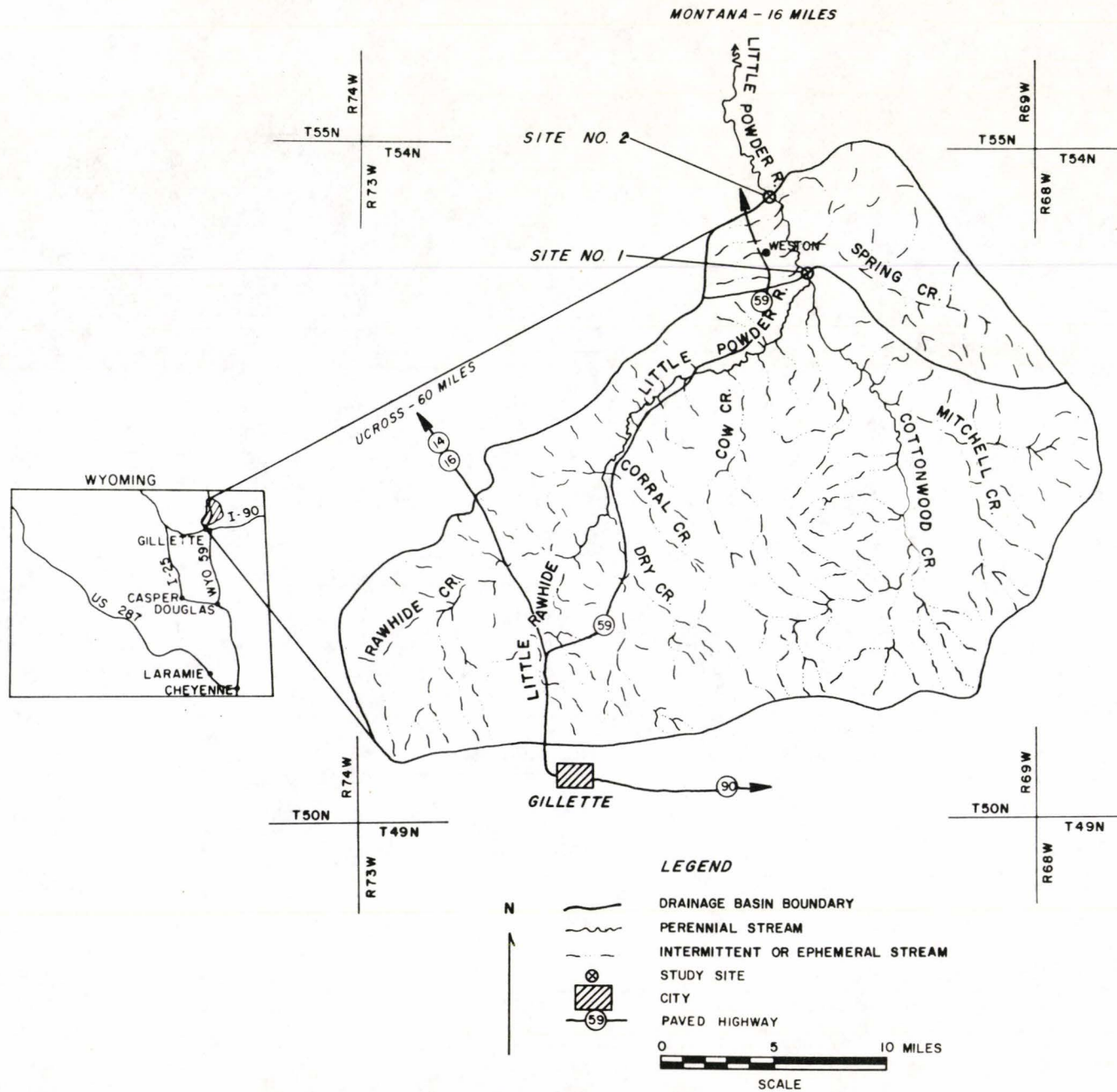
as to the total amount of dissolved material, the individual ions present and the relative importance of each ion in the solution at the time of collection.

Nutrient and organic concentrations are generally indicative of recently received waste loads. The wastes can reach the stream either from point discharges or from non-point runoff. Other sources for some of these compounds include natural drainage and certain of the blasting preparations used in mining. This current effort was designed to collect background data for conditions assumed to be natural to the drainages.

Trace metals and elements, as the name implies, are generally found in waters in minute concentrations. The ability of a ground water source contributory to a stream to solubilize and transport these materials is related to pH, contact time, valency, the presence of various optimum strata and other currently unquantified complexities. Mining or similar activity in an area can theoretically create more

conditions for these processes to occur as more surface area is exposed to chemical and physical reactions. This investigation sought to establish baselines against which the effects of future development in the area could be gauged.

Figure 1. Little Powder River
Drainage Basin.



CHAPTER III
DESCRIPTION OF STUDY AREAS

Little Powder River

The Little Powder River is one of only several perennial streams occurring in Campbell County of northeastern Wyoming (Figure 1). The topography is dominated by plains, low lying hills and table lands to the east with rough hills and gentle mountain ridges forming the west boundary of the basin. The Little Powder River is a major tributary of the Powder River within the Yellowstone River Basin of Wyoming. The headwaters rise in the Rawhide drainage (elevation 1463 meters MSL) immediately north of Gillette, Wyoming, and flow 142 kilometers to its confluence with the Powder River (elevation 1100 meters MSL) in southeast Montana. The total drainage area of the basin is 4,545 square kilometers.

The Little Powder River basin can be characterized primarily as a semiarid natural short grass plains area (average annual precipitation approximately 36 centimeters). Major vegetation types within the basin include: big sage brush (Artemisia tridentata), silver sage brush (Artemisia cana), black greasewood (Sarcobatus vermiculatus), ponderosa pine (Pinus ponderosa), plains cottonwood (Populus sargentii), and prairie grasses (Spartina pectinate, Deschampsia caespatesis, Elymus sp., and Agropyron sp.) (United States Department of the Interior, 1974).

Coincident with this natural setting, major land uses in the past have included: 1) grazing lands for livestock; 2) production of native

hay; and, 3) wildlife habitat for deer, pronghorn antelope and upland game birds. At present, coal development is being initiated in the upper basin by the AMAX Coal Company, the Peabody Coal Company and the Carter Oil Company. The Carter mine (Rawhide mine) is expected to produce 12 million tons per year and begin production in July, 1977. In 1976 the Rawhide mine discharged a small amount of good quality ground water into the Little Powder River drainage, augmenting its natural flow. Communication with Carter indicates this discharge has been discontinued and will remain so. The AMAX North mine is expected to go into production within a year and by 1984 will produce 20 million tons of coal per year. Peabody has not yet started mining operations on its holding. Also being discussed are projects for water storage development.

The Little Powder River lies in the Fort Union Formation, tertiary rock of the Paleocene era. The formation is composed of three members:

- 1) The Tullock Member (lowermost)--290 to 396 meters thick--light gray to tan, even bedded sandstone (massive to thin); dark gray and brown siltstone; shale and carbonaceous shale; thin coal beds.

- 2) The Lebo Shale Member (middle)--518 to 853 meters thick where undifferentiated from the Tongue River Member--mostly medium and dark gray, fine-grained to conglomeratic sandstone: brownish carbonaceous shale; thin to thick coalbeds.

- 3) The Tongue River Member (uppermost)--244 meters thick--inter-bedded light gray, fine-grained sandstone; siltstone; sand; shale; coalbeds.

The coalbeds in the Tullock Member are thin and parted. However, the thick, persistent coalbeds located near the top of the formation in the eastern part of the basin are suitable for strip mining (U.S. De-

partment of the Interior, 1974). Oil and gas are other mineral resources found in the vicinity of the Little Powder River.

Streamflow records for the Little Powder River, as measured at U.S.G.S. Gage Station No. 06324970 located 32 kilometers north of Weston, Wyoming, and 8 kilometers south of the Wyoming-Montana border, indicate that spring runoff normally occurs during late April, May and early June. A maximum discharge of $28.3 \text{ m}^3/\text{sec}$ (1000 cfs) was measured on January 17, 1974, while periods of no flow were recorded during July and August of 1973. During the remainder of the year, discharges normally remain below $0.28 \text{ m}^3/\text{sec}$ (10 cfs) (Figure 2).

The study area was limited to the 8 kilometer section of the stream running across the southwest corner of the Thunder Basin National Grassland in Campbell County, Wyoming. During the 1974 field studies three sites were sampled (see Wesche, Kerr and Baldrige, 1975). However, in 1975 the middle site at Soda Well was deleted, leaving the following two stations:

No. 1) T 54 N, R 70 W, S 32--on the Loral Leaf Ranch owned by Mr. Frank Ray, 0.4 kilometers below the confluence of Cottonwood Creek near the south boundary of Thunder Basin at an elevation of 1,137 meters above msl. (See Figures 1 and 3.)

No. 2) T 54 N, R 70 W, S 7 and T 54 N, R 71 W, S 12--on the Norfolk Ranch at the west boundary of Thunder Basin at an elevation of 1,119 meters above msl. (See Figures 1 and 3.)

Site No. 1

Above this site, the Little Powder River basin encompasses 1,222

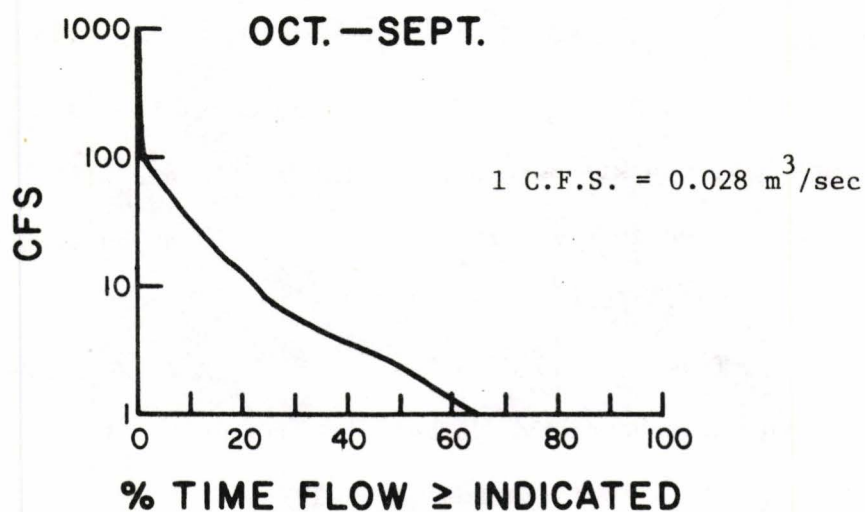
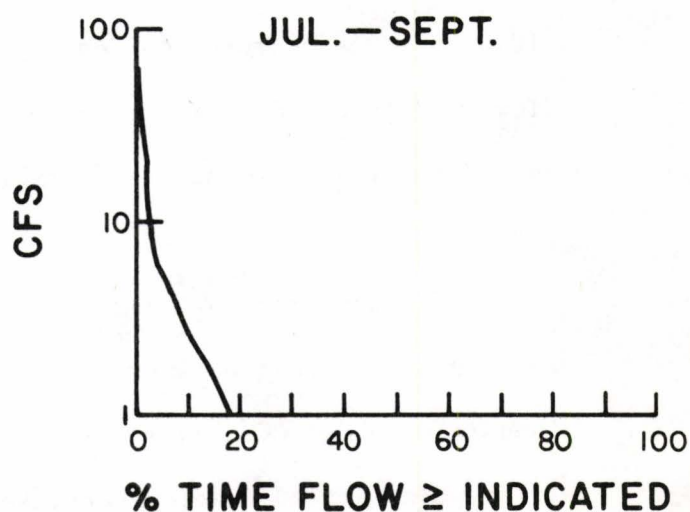
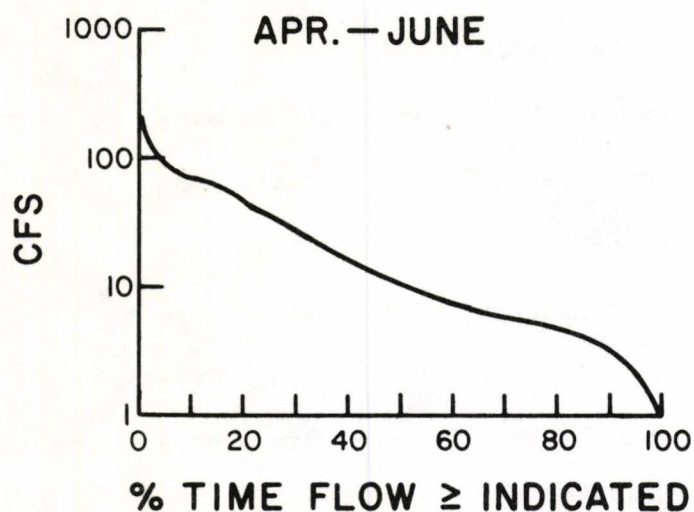
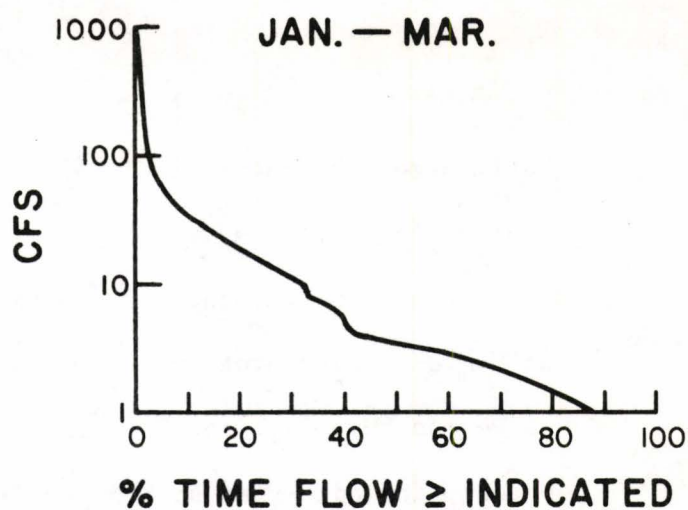
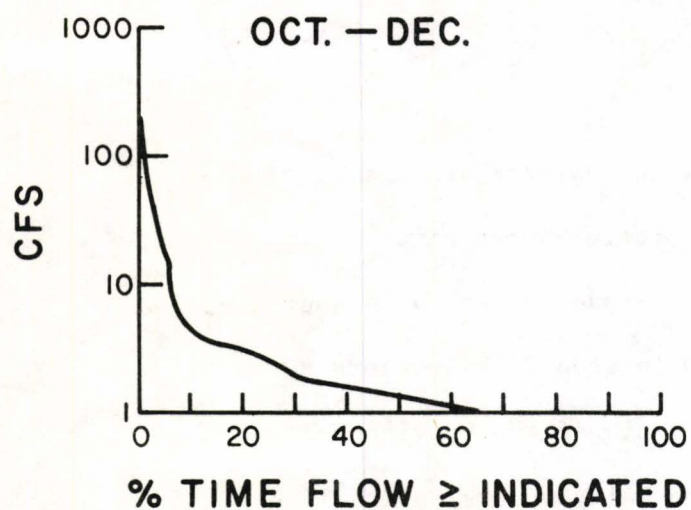


Figure 2 . Seasonal and Annual Flow Duration Curves for the Little Powder River, 1973 to 1975.



Figure 3. Little Powder River.
Top: Site No. 1, June, 1976.
Bottom: Site No. 2, June, 1976.

square kilometers and is drained by 653 kilometers of perennial and intermittent stream channels. Drainage density is 0.86. In this area, as well as at Site No. 2, the Little Powder is a fifth-order stream.

Site No. 1 was a 104-meter long straight reach covering 421 square meters. Hydraulically, this stream section was quite homogeneous with stream widths varying only from 3.7 to 4.0 meters, while over 85 percent of the surface area was at least 0.3 meter in depth. Streamflow at the sampling times ranged from $.26 \text{ m}^3/\text{sec}$ (8.9 cfs) in June down to zero flow in January. Due to the flat gradient of the section (0.67 meter per kilometer), the substrate was composed of inorganic muck and fine sand, sediments which had settled out of the water. This, in conjunction with the steep streambanks which were present (range, 0.2:1 to 2.6:1), made access to and movement in the channel quite difficult during sample collection.

Small amounts of filamentous green algae were in evidence at Site No. 1, while along the streambanks and on the floodplain adjacent to the channel, grasses, sedges, sage brush, greasewood and cottonwood trees were observed. While sampling here, mule deer, antelope, sandhill cranes, cottontail rabbits, and ring-necked pheasants were seen by the investigators.

Site No. 2

Above Site No. 2, the Little Powder drains an area of 1,427 square kilometers which contains a total of 755 kilometers of perennial and intermittent channels. Drainage density of the basin is 0.85.

Site No. 2 was a relatively straight stream reach 82 meters long having a surface area of 503.5 square meters. Due to its steeper stream gradient (1.80 meters per kilometer) and greater channel widths (up to

7 meters), water depths at Site No. 2 were somewhat shallower than those at Site 1, while mean velocities ranged higher. Approximately 60 percent of the surface area had water depths of less than 0.3 meter. The substrate composition at Site 2 was found to be more diverse than that at Site 1. Along the thalweg in the upstream half of the study section, areas of fine gravel were present. The remainder of the substrate was of inorganic muck and sand. Bank slopes varied substantially at this site, ranging from 0.5:1 to 7.5:1. Streamflow at the sampling times ranged from $.50 \text{ m}^3/\text{sec}$ (16.2 cfs) in June down to zero flow in January.

As at Site No. 1, small amounts of filamentous green algae were observed. Grasses and sedges, interspersed with wild rose, grew along the streambanks, while the adjacent floodplain was primarily covered with grasses and scattered cottonwood trees. Deer, pheasants and racoon tracks were abundant in the area while evidence of beaver activity was found at the upper end of the section.

Antelope Creek

The headwaters of Antelope Creek rise on the east side of Pine Ridge near the Converse County-Natrona County boundary line in east-central Wyoming and flow intermittently 90 kilometers to the east before confluencing with the Dry Fork of the Cheyenne River to form the Cheyenne River near Dull Center (Figure 4). From this point, the Cheyenne flows easterly out of Wyoming to central South Dakota, where it joins the Missouri River. In Wyoming, the Cheyenne drains a total of 17,888 square kilometers of land (Person, 1939) whose elevation ranges from approximately 1,100 meters above msl at the state line to over 1,830 meters above msl at the headwaters.

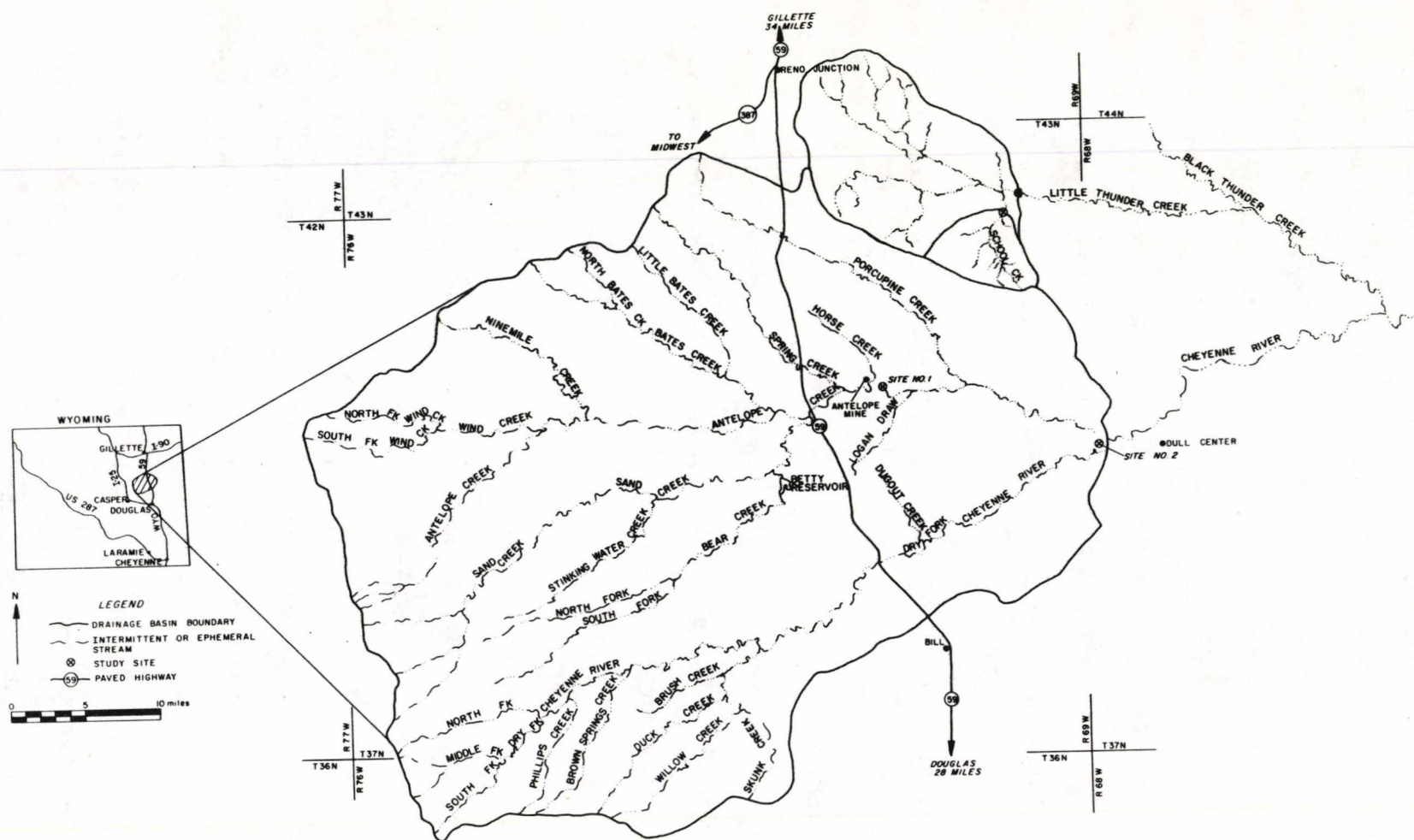


Figure 4. Location Map Showing Antelope Creek, School Creek and Little Thunder Creek.

The Antelope Creek basin can be characterized as semiarid range-land dominated by big sage brush/shortgrass plains, and low-lying hills and tablelands, dotted with occasional isolated uplands, breaks, knobs and ridges. The stream has a wide, flat floor and a broad floodplain covered in many areas with stands of plains cottonwood (Populus sargentii) and willow (Salix sp.). Average annual precipitation is approximately 30-36 centimeters per year (United States Department of the Interior, 1974). Figure 5 provides general views of the basin.

Historic land uses in the Antelope Creek drainage are similar to those described for the Little Powder basin, namely, livestock grazing, hay production and wildlife habitat. In recent years oil production has been on the increase as evidenced by the many new roads and operating wells which dot the landscape. The basin is also underlain by rich deposits of sub-bituminous coal and, while full-scale development of the resource has not yet begun, it can be foreseen in the near future. In the past, limited amounts of coal have been produced at the Antelope mine, while at present, the Peabody Coal Company and Pacific Power and Light hold federal leases in the basin and have proposed opening mines sometime in the future.

Streamflow records for Antelope Creek are non-existent. The nearest U.S.G.S. gage station (No. 06386500) with records is located approximately 105 kilometers downstream from the lowest study site on the Cheyenne River proper near Spencer, 8 kilometers west of the South Dakota border. These records indicate that spring runoff normally occurs in April and May, with the maximum discharge of record being $453 \text{ m}^3/\text{sec}$ (16,000 cfs) on May 27, 1962. During the late summer and

early fall, periods of zero flow are quite common. From 1948 to 1974, the average discharge was $1.65 \text{ m}^3/\text{sec}$ (1.65 cfs) (U.S. Department of the Interior, 1974). A new gage has been installed by the U.S.G.S. at the same location on Antelope Creek as study Site No. 2. No records are currently available for this gage. Presumably some information will be accessible for use this coming year.

Two study sites were investigated on Antelope Creek, all within the boundaries of the Grassland and accessible by vehicle. In 1975 three sites were examined, but in 1976 the middle site (below the mouth of Porcupine Creek) was eliminated. The sites investigated in 1976 were:

No. 1) T 41 N, R 71 W, Section 36--below the Antelope mine at the junction of the Irwin Road and Hilight Road.

No. 2) T 40 N, R 68 W, Section 20--near the Fiddleback Ranch just above the river crossing on the Rochelle Hills Road and immediately below the confluence of Antelope Creek and the Dry Fork of the Cheyenne River.

Figure 4 shows the location of these sites while Figure 5 depicts the habitat present at each.

Site No. 1

Above this site, the Antelope Creek basin encompasses 2,092 square kilometers and is drained by 1,362 kilometers of intermittent stream channels. Drainage density is 1.05. At this location, as well as at Site 2, Antelope Creek is a fifth-order stream.

Site No. 1 was a 91-meter-long straight reach varying in width from 8 to 16 meters and covering approximately 1,133 square meters. Water depths ranged up to 0.6 meter in the upper 46 meters of the



Figure 5. Antelope Creek.
Top: Site No. 1, June, 1976.
Bottom: Site No. 2, September, 1976.

section, while in the lower half, no depths exceeded 0.3 meter. Stream-flow at the sampling times ranged from $0.19 \text{ m}^3/\text{sec}$ (14.1 cfs) in April down to zero in both September and January. Due in part to the exceptionally flat gradient of the section (0.07 meter per kilometer) the substrate was composed primarily of silt and fine sand.

Aquatic vegetation was quite dense at Site No. 1, being composed primarily of filamentous green algae and Chara sp. In fact, during the June fish sampling operation, these heavy growths hampered seining to such a degree that accurate population estimates could not be made. Waterfowl and toads were observed at this site during our sampling visits.

Site No. 2

Above Site No. 2, Antelope Creek drains an area of 3,874 square kilometers containing 2,391 kilometers of intermittent and perennial channels. As at Site 1, drainage density is low, 0.99.

Of the two sites, No. 2 (91 meters long) had the greater wetted width (range 15-17 meters) and surface area (1,895 square meters) and had the shallower depths (less than 0.3 meter throughout the area). While the gradient was steeper here than at Site No. 1, it was still exceptionally flat at 0.13 meter per kilometer. The substrate was primarily soft mud, with scattered areas of fine sand. Flow on the sampling dates ranged from $0.68 \text{ m}^3/\text{sec}$ (9.9 cfs) in June down to zero in January.

Aquatic vegetation was sparse throughout the year. Riparian vegetation, consisting primarily of various grasses, sedges and cottonwood trees, was very lush in June. Raccoon tracks, deer tracks and toads were abundant at this location.

Little Thunder Creek

Little Thunder Creek rises just south of Reno Junction and flows for 32 kilometers intermittently in an easterly direction into Black Thunder Creek, a major tributary of the upper Cheyenne River. Elevation of the Little Thunder Creek drainage basin ranges from 1,550 meters to 1,310 meters above msl (see Figure 4).

The Little Thunder Creek basin is predominantly semiarid rangeland (big sage brush/shortgrass plains) with low-lying hills, tablelands, breaks and ridges. A portion of the drainage lies in the Rochelle Hills, an area characterized by ponderosa pine covered ridges and hills. Plains cottonwood inhabit the wide, flat floodplain. Average annual precipitation is the same as for the Antelope Creek basin (30 to 36 centimeters per year).

Figure 6 presents a general view of Little Thunder Creek, while Figure 4 shows the location of the stream and the sampling site.

Historic land uses in the Little Thunder Creek basin are the same as for the Antelope Creek watershed (see description of Antelope Creek basin). Atlantic Richfield Company's Black Thunder coal mine, scheduled to begin production in early 1978 and reach the 10 million ton production level within 5 years, is located in the Little Thunder Creek drainage. The lifespan of this mine is projected to be at least 40 years, with an estimated peak production capability of 20 million tons per year. No streamflow records exist for Little Thunder Creek, the nearest U.S.G.S. gage stations being located on the Cheyenne River (see description of Antelope Creek).

One study site was investigated on Little Thunder Creek, location T 43 N, R 69 W, Section 29--just below the mouth of School Creek. This

site is located on Thunder Basin National Grassland and is accessible by vehicle.

Study Site (Figure 6)

Above this site, the Little Thunder Creek basin encompasses 396 square kilometers with 158 kilometers of intermittent stream channels and a drainage density of 0.64. Little Thunder Creek is a fifth-order stream at the study site.

The study site was 79 meters long, between 2.6 and 4.3 meters in width and covered approximately 288 square meters. Maximum water depths at the sampling times ranged between 1.2 and 0.1 m. Stream-flow varied from $0.04 \text{ m}^3/\text{sec}$ (1.4 cfs) (June) down to zero (September and January). The gradient was approximately .95 meter per kilometer and the substrate was composed primarily of mud and debris.

Dense aquatic vegetation (including pond reeds, filamentous algae and Chara sp.) was present in June and September. Frogs, deer, antelope and cottontail rabbits were observed during sampling visits. The Rochelle Hills extend to within 0.8 kilometer of this sampling site.

School Creek

School Creek headwaters in the northwest Rochelle Hills and flows intermittently 13 kilometers in a northerly direction into Little Thunder Creek. The School Creek drainage area varies between 1,550 meters and 1,400 meters above msl (see Figure 4).

Much of the upper School Creek watershed lies within the Rochelle Hills and is characterized by ponderosa pine-meadow hills and ridges. The remainder of the School Creek basin is typically big sage brush/shortgrass semiarid rangeland. The floodplain contains scattered



Figure 6. Top: School Creek, September, 1976.
Bottom: Little Thunder Creek, June, 1976.

plains cottonwood. Average annual precipitation is similar to that of the Little Thunder Creek and the Antelope Creek watersheds (30-36 centimeters per year).

Historic land uses for the School Creek basin are the same as for the Little Thunder Creek and Antelope Creek basins (see description of Antelope Creek basin). No major mining developments are planned for the School Creek drainage in the near future. A general view of School Creek is shown in Figure 6. No streamflow records exist for School Creek (see descriptions of Little Thunder Creek and Antelope Creek).

One study site in Thunder Basin National Grassland on School Creek was investigated. This site is located in T 43 N, R 69 W, Section 32-- just above the confluence with Little Thunder Creek (Figure 4).

Study Site (Figure 6)

Above this site, the School Creek basin encompasses 67 square kilometers with 37 kilometers of intermittent stream channels and a drainage density of 0.91. School Creek is a fourth-order stream.

The study site was 79 meters long, 0.9 to 2.9 meters in width and covered approximately 144 square meters. Maximum water depths ranged between 0.9 and 0.1 meter at the sampling times, while discharge varied from zero (September and January) to approximately $0.01 \text{ m}^3/\text{sec}$ (0.4 cfs) (May and June). The gradient in this reach was quite gentle, measuring less than 0.6 meter per mile. The substrate was primarily comprised of mud and debris. Pond reeds and filamentous algae were observed, as were cottontail rabbits, jackrabbits, waterfowl, antelope, frogs, toads and a garter snake. The northeast edge of the Rochelle Hills extends to within 0.4 kilometer of this site.

CHAPTER IV

RESULTS

Biological

Fisheries

Overall, fish sampling efforts during June 1976 were severely hampered. Standing crop estimates could be conducted only at Little Powder River Site #1, while at the other five sites, a combination of deep water and dense growths of aquatic vegetation (primarily Chara sp.) reduced sampling efficiency to such a degree that reliable estimates could not be obtained. For these latter sites, relative abundance is reported instead.

Taxonomic classification of the fish species thusfar collected from the Little Powder River (sampled, 1974-76), Antelope Creek (1975-76) and School-Little Thunder Creeks (1976) is presented in Table 2. Species common to all four streams include fathead minnows, white suckers, and black bullheads. Green sunfish have been collected in all but School Creek. Of the 16 species listed, all but 3 have been found in the Little Powder, while 10 are present in Antelope Creek, 6 in Little Thunder and 3 in School Creek.

Members of the Family Cyprinidae (minnows) predominate the species list, comprising 6 of the 16 taxa collected. Three species each have been sampled from the Families Catostomidae (suckers) and Centrarchidae (sunfishes).

To date, 5 game fish species have been collected in Thunder Basin waters: black bullheads, green sunfish, stonecat, bluegill and

TABLE 2

TAXONOMIC CLASSIFICATION OF FISHES COLLECTED FROM THE STUDY STREAMS (1974-1976)

CLASS - OSTEICHTHYES (bony fishes)
 SUBCLASS - ACTINOPTERYGII (ray-finned fishes)

<u>Order</u>	<u>Family</u>	<u>Genus</u>	<u>Species</u>	<u>Stream</u>
Clupeiformes	Hiodontidae (mooneyes)	<u>Hiodon</u>	<u>alosoides</u> (Rafinesque) (goldeye)	LPR
Cypriniformes	Cyprinidae (minnows)	<u>Cyprinus</u>	<u>carpio</u> (Linnaeus) (carp)	LPR, AC
		<u>Hybopsis</u>	<u>gracilis</u> (Richardson) (flathead chub)	LPR, AC
		<u>Rhinichthys</u>	<u>cataractae</u> (Valenciennes) (longnose dace)	LPR, AC
		<u>Notropis</u>	<u>stramineus missouriensis</u> (Cope) (sand shiner)	LPR, AC
		<u>Pimephales</u>	<u>promelas</u> (Rafinesque) (fathead minnow)	LPR, AC, SC, LTC
		<u>Hybognathus</u>	<u>placitus</u> (Girard) (plains minnow)	LPR, AC
	Catostomidae (suckers)	<u>Carpionodes</u>	<u>carpio</u> (Rafinesque) (river carpsucker)	LPR
		<u>Moxostoma</u>	<u>macrolepidotum</u> (Lesueur) (northern redhorse)	LPR
		<u>Catostomus</u>	<u>commersoni</u> (Lacépède) (white sucker)	LPR, AC, SC, LTC
		<u>Ictalurus</u>	<u>melas</u> (Rafinesque) (black bullhead)	LPR, AC, SC, LTC
	Ictaluridae (North American catfishes)	<u>Noturus</u>	<u>flavus</u> (Rafinesque) (stonecat)	LPR
		<u>Lepomis</u>	<u>cyaneus</u> (Rafinesque) (green sunfish)	LPR, AC, LTC
		<u>Lepomis</u>	<u>macrochirus</u> (Rafinesque) (bluegill)	LTC
		<u>Micropterus</u>	<u>salmoides</u> (Lacépède) (largemouth bass)	LTC
Perciformes	Centrarchidae (sunfishes)	<u>Lepomis</u>	<u>microchirus</u> (Rafinesque) (bluegill)	LTC
		<u>Micropterus</u>	<u>salmoides</u> (Lacépède) (largemouth bass)	LTC
Cyprinodontiformes	Cyprinodontidae (killifishes)	<u>Fundulus</u>	<u>kansae</u> (Garman) (plains killifish)	AC

LPR = Little Powder River

SC = School Creek

AC = Antelope Creek

LTC = Little Thunder Creek

largemouth bass. The former 2 species appear to be quite widespread throughout the Basin, while the latter 3 have each been found at only one location. Parker (1976) reports that in June of 1975 the Wyoming Game & Fish Department surveyed Reno Reservoir (located upstream from our study site in the Little Thunder Creek drainage) and collected both largemouth bass and bluegill. This reservoir is most likely the source of the individuals we collected at our Little Thunder site. One stonecat was seined from Little Powder River Site #2 in June of 1976. While this is the first recorded capture of the species in this stream, Baxter and Simon (1970) do report its occurrence in the Powder River drainage. Another game fish species, the channel catfish, is listed by Baxter and Simon as an inhabitant of the Little Powder; however, WRII has not collected any to date.

No species listed in Table 2 is considered as "threatened" by the Department of the Interior, although the goldeye (collected in Little Powder River, 1974) is listed in Wyoming's Rare & Endangered Wildlife (Wyoming Game & Fish Department) as "status undetermined."

Little Powder River. Relative abundance and length-weight data for the fish collected at the two study sites during 1976 are presented in Table 3, while standing crop estimates for Site #1 (1974-76) appear in Table 4.

The number of species collected (or observed) at the sites was again found to fluctuate quite widely between sampling years. At Site #1, only 4 species were recorded (10 in 1975, 7 in 1974), while at #2, an increase to 9 was observed, as compared with only 3 in 1975 (11 in 1974). The plots of fish species diversity shown in Figure 7 illustrate this fluctuation. However, should the diversity values for both

TABLE 3

FISH LENGTH, WEIGHT AND SPECIES COMPOSITION DATA

LITTLE POWDER RIVER, JUNE 1976

Species	Number	% Total Number	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Weight Range (g)
SITE #1						
Black Bullhead	2	1.5	67.0	64-70	8.5	-
Green Sunfish	1	0.7	41.0	-	2.0	-
Sand Shiners	123	91.1	all less than 65 mm		0.5	-
Fathead Minnows	9	6.7	all less than 65 mm		1.3	-
SITE #2*						
Black Bullhead	2	5.0	138.0	121-155	39.0	28-50
Stonecat	1	2.5	180.0	-	58.0	-
Sand Shiners	26	65.0	all less than 65 mm		1.0	-
Fathead Minnows	4	10.0	all less than 38 mm		0.5	-
Flathead Chub	2	5.0	128.0	125-131	19.0	18-20
Plains Minnow	5	12.5	76.0	-	4.0	-

*Green sunfish, white suckers and river carpsuckers were also observed, but not captured.

TABLE 4

STANDING CROP ESTIMATES FOR FISH SPECIES COLLECTED AT LITTLE POWDER RIVER SITE #1

JUNE 1974, 1975 AND 1976

Species	1974				1975				1976			
	No./Hct. (No./Km)	% Numbers	Kg/Hct. (Kg/Km)	% Weight	No/Hct. (No./Km)	% Numbers	Kg/Hct. (Kg/Km)	% Weight	No/Hct. (No./Km)	% Numbers	Kg/Hct. (Kg/Km)	% Weight
Black Bullhead	808 (322)	11.0	21.1 (8.4)	28.0	541 (220)	11.6	6.6 (2.7)	12.4	48 (19)	1.5	0.4 (0.2)	18.6
Green Sunfish	711 (285)	9.7	7.8 (3.1)	10.3	385 (157)	8.3	3.6 (1.5)	6.9	24 (10)	0.7	0.05 (0.02)	2.3
River Carpsucker	0	0	0	0	52 (21)	1.1	14.7 (6.0)	27.9	0	0	0	0
Northern Redhorse	0	0	0	0	52 (21)	1.1	3.7 (1.5)	7.1	0	0	0	0
White Sucker	902 (361)	12.3	35.9 (14.4)	47.6	437 (179)	9.4	16.7 (6.8)	31.8	0	0	0	0
Plains Minnow	0	0	0	0	180 (73)	3.9	1.2 (0.5)	2.4	0	0	0	0
Sand Shiner	4466 (1784)	60.8	6.8 (2.7)	9.0	2831 (1153)	60.8	2.6 (1.0)	4.9	2922 (1187)	91.1	1.4 (0.6)	65.1
Carp	72 (29)	1.0	2.7 (1.1)	3.6	25 (11)	0.5	0.2 (0.1)	0.4	0	0	0	0
Flathead Chub	0	0	0	0	128 (53)	2.8	3.2 (1.3)	6.0	0	0	0	0
Fathead Minnow	356 (143)	4.9	1.1 (0.5)	1.5	25 (11)	0.5	0.1 (0.03)	0.2	214 (87)	6.7	0.3 (0.1)	14.0
Longnose Dace	25 (9)	0.3	0.02 (0.01)	<0.1	0	0	0	0	0	0	0	0
TOTALS	7340 (2933)	100.0	75.4 (30.2)	100.0	4656 (1899)	100.0	52.6 (21.4)	100.0	3208 (1303)	100.0	2.15 (0.92)	100.0

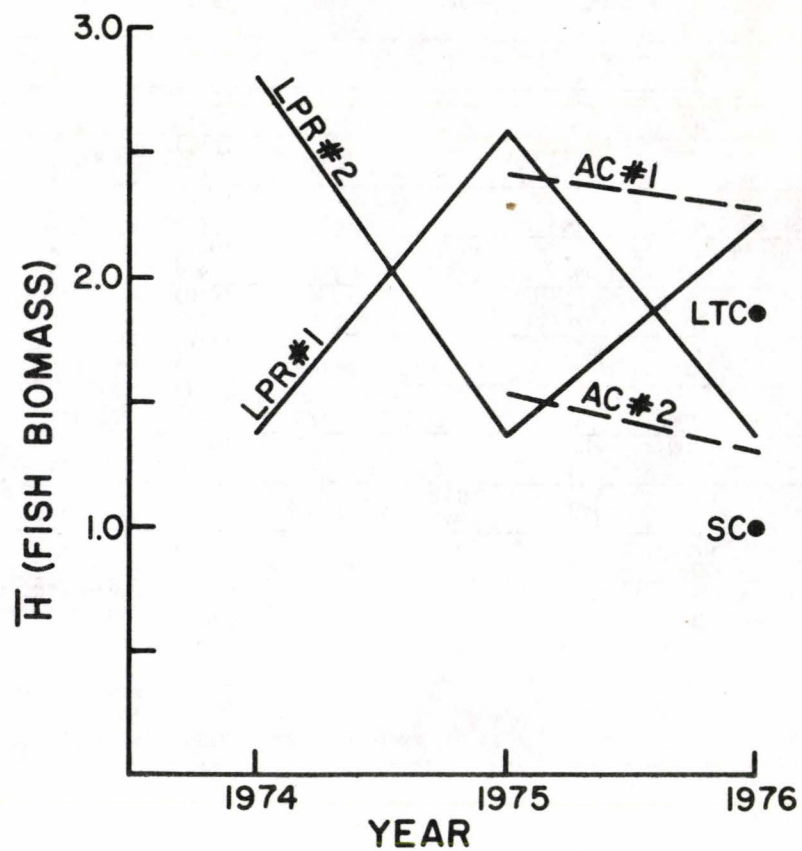
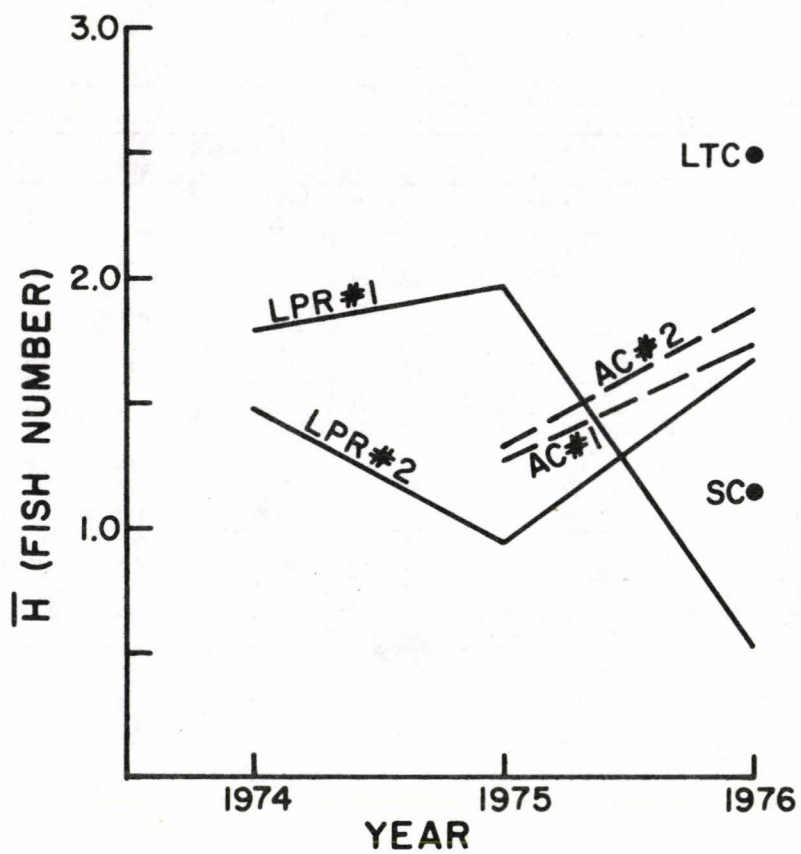


Figure 7. Mean Shannon Diversity Index Values for the Fish Populations Sampled from the Four Study Streams, 1974-1976.

sites in each year be averaged and this plot drawn, we would observe little change over the sampling years. This would tend to indicate that natural movement of fish into and out of the study sections is responsible for this fluctuation, not response to environmental change.

Sand shiners remained the predominant species at both sites, comprising 91.1% of the catch at #1 and 65.0% at #2. Considering biomass, sand shiners also predominated at #1 (65.1% of catch), while black bullheads contributed 35.1% at #2. However, numerous large river carpsuckers, as well as green sunfish and white suckers, were observed avoiding our seines at #2, due primarily to the high water conditions encountered ($0.50 \text{ m}^3/\text{sec}$). This may also be the explanation for the exceptionally low standing crop estimate at Site #1, although fish avoidance was not directly observed.

Antelope Creek. Relative abundance and length-weight data for fish collected at the two Antelope Creek sites are presented in Table 5.

Both the number of species sampled and the total number of individual fish collected at both sites were found to decline from 1975 to 1976. Speciation decreased from 8 to 6 at Site #1 and from 9 to 5 at #2, while the reduction in total numbers was much more dramatic (324 down to 38 at #1, 1728 down to 11 at #2). Extremely high water (especially at Site #2) and dense stands of aquatic vegetation (especially at #1) markedly reduced sampling efficiency, resulting in these declines. Despite these reductions, Figure 7 indicates an increase in community diversity based upon fish numbers and only a slight decrease when considering biomass. While this may seem rather unusual, it must be kept in mind that the Shannon-Weaver diversity index is based not only on the richness or number of species and the total

TABLE 5

FISH LENGTH, WEIGHT AND SPECIES COMPOSITION DATA

ANTELOPE CREEK, JUNE 1976

Species	Number	% Total Number	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Weight Range (g)
SITE #1						
Black Bullhead	3	7.9	all less than 70 mm		9.3	-
Green Sunfish	3	7.9	all less than 55 mm		1.0	-
Sand Shiners	5	13.2	all less than 71 mm		2.4	-
Fathead Minnow	24	63.2	all less than 73 mm		1.7	-
Plains Minnow	1	2.6	80.0	-	14.0	-
White Sucker	2	5.2	85.5	85-86	20.0	-
SITE #2*						
Sand Shiner	4	36.4	56.8	52-60	1.0	-
Fathead Minnow	1	9.0	62.0	-	8.0	-
Flathead Chub	3	27.3	107.3	90-140	12.0	10-14
Plains Killifish	3	27.3	43.3	38-48	1.0	-

*One dead black bullhead observed.

number of individuals present, but also the distribution of those individuals among the species (EPA, 1973). The low sampling efficiency we experienced in 1976 also cannot be overlooked.

At Site #1, fathead minnows remained the predominant species, comprising 63.2% of the numbers collected and 29.6% of the biomass. Due to the small sample size, little can be said regarding a predominant species at Site #2. Sand shiners, fathead minnows, flathead chubs and plains killifish were collected in about equal numbers.

School-Little Thunder Creeks. Relative abundance and length-weight data for fish collected at the School and Little Thunder Creek sites are presented in Table 6. Standing crop estimates could not be made because of the reduction in sampling efficiency caused by deep water and dense aquatic vegetation.

At the School Creek site, white suckers predominated on both a numbers and a biomass basis, comprising 71.4% and 75.1% of the sample, respectively. Lesser numbers of black bullheads and fathead minnows were also collected. Diversity of the fish community (Figure 7) generally ranged lower than at the other sampling stations, due most likely to the extensive channel dewatering which occurs. During the September visit to the site, only a few shallow (≤ 0.5 ft) scattered pools remained in the reach of stream.

Fish diversity was found to be higher at the Little Thunder site (Figure 7), although the numbers collected were similar to those for School Creek. The pool selected for study on Little Thunder is apparently fed by ground water, as water levels throughout the year did not vary greatly.

Four game fish species were collected from Little Thunder: black

TABLE 6

FISH LENGTH, WEIGHT AND SPECIES COMPOSITION DATA

JUNE, 1976

Species	Number	% Total Number	Mean Length (mm)	Length Range (mm)	Mean Weight (g)	Weight Range (g)
SCHOOL CREEK						
Black Bullhead	2	14.3	115.0	70-160	49.0	20-78
Fathead Minnow	2	14.3	73.5	67-80	12.0	-
White Sucker	10	71.4	125.5	74-220	36.7	12-120
LITTLE THUNDER CREEK						
Black Bullhead	1	12.5	160.0	-	72.0	-
Green Sunfish	1	12.5	155.0	-	72.0	-
Bluegill	2	25.0	179.5	179-180	125.0	110-140
Largemouth Bass	1	12.5	80.0	-	4.0	-
Fathead Minnow	2	25.0	47.5	45-50	1.0	-
White Sucker	1	12.5	200.0	-	90.0	-

bullheads, green sunfish, bluegill and largemouth bass. As discussed earlier, the source for the latter two species is most likely Reno Reservoir, located upstream. Except for the one bass, these specimens were of "fishable" size. This would indicate that with proper management, a fisheries potential does exist for these deep, ground water fed ponds which are scattered along the creek in this reach. However, the area's distance from population centers may limit angler use.

Other species collected at the Little Thunder site included fathead minnows and white suckers.

Biology of Species Collected (1974-1976)

Green Sunfish (Lepomis cyaneus). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Hunter, 1963.)

Adult Size: Approximately 20 cm.

Life Expectancy: seven to nine years.

Range: Widely distributed in the U. S., from the Great Lakes to the Mexican Border and from the Alleghenies to the Rocky Mountains. In Wyoming, primarily in the northeastern counties and also in the North Platte, Big Horn and Niobrara river systems.

Preferred Habitat: Pools of small and medium sized streams.

Sometimes abundant in small lakes, ponds and sloughs.

Feeding Habits: Carnivorous, feeding primarily on insects, molluscs and small fishes.

Spawning Habits: Individuals reach sexual maturity at two to three years of age. Spawning normally occurs during the spring and early summer (20°C to 28°C) over substrates of mud, silt, sand or aquatic vegetation in pools having water depths

ranging from 4 cm to 46 cm. Eggs are deposited in a nest built by the male and hatch in three to five days. Members of the species are prolific spawners and often overpopulate their warm water habitats.

Comments: At the Little Powder River and Antelope Creek study sites in 1975, it appeared that spawning had occurred prior to the June sampling and the eggs had hatched. This was indicated by the number of fish in the 3 cm to 5 cm size group.

Black Bullhead (Ictalurus melas). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Forney, 1955; Wallace, 1967; Black, 1953.)

Adult Size: Average 13 cm to 18 cm, but up to 38 cm.

Life Expectancy: Approximately nine years.

Range: From the East coast west to the Rocky Mountains and from Manitoba south to Tennessee. In Wyoming, found in all drainages east of the Continental Divide on the plains.

Species can tolerate water temperatures to mid 30°C range and very low dissolved oxygen concentrations.

Preferred Habitat: Low gradient, turbid, warm-water streams and ponds.

Feeding Habits: Primarily carnivorous, including aquatic insects, snails, crustaceans and small fish. Also feed on plant material.

Spawning Habits: Spawning normally occurs during the spring and early summer (approximately 21°C) in shallow pool area having substrates of mud, silt, sand or rooted aquatic vegetation. Each mating pair builds at least five nests, with approxi-

mately 200 eggs deposited in each. Eggs hatch in five days and the fry are guarded by one or both parents. Members of this species are prolific spawners and often overpopulate their habitat unless intensively managed as a fishery.

Comments: At the Little Powder River study sites in 1975, it appeared that spawning had occurred prior to the June sampling and the eggs had hatched. This was indicated by the number of fish collected in the 3 cm to 5 cm size class.

Sand Shiner (Notropis stramineus missouriensis). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Minckley, 1973; Carlander, 1969; Starrett, 1951.)

Adult Size: Normally 5 cm to 8 cm.

Life Expectancy: Three to four years.

Range: Rocky Mountains east to the St. Lawrence drainage. In Wyoming, all drainages east of the Continental Divide, except the headwaters of the Madison and Yellowstone rivers in Yellowstone Park.

Preferred Habitat: Warm, perennial, sandy streams and sandy, shallow lakes with little rooted aquatic vegetation.

Feeding Habits: Omnivorous, including aquatic and terrestrial insects and diatoms.

Spawning Habits: Individuals normally become sexually mature at one year of age. Spawning occurs in the summer from June to August over sand and clean gravel areas. Each female produces from 250 to 3,000 eggs which are scattered over the stream substrate. No nest construction or parental care is known to occur.

Comments: Excellent forage species in Wyoming. No spawning activity or gravid specimens were noted during WRRI's 1974 and 1976 collections. Ripe females were collected on Antelope Creek in June, 1975.

Fathead Minnow (Pimephales promelas). (From: Baxter and Simon, 1970; Markus, 1934; Simpson, 1941; Scott and Crossman, 1973; Wynne-Edwards, 1932.)

Adult Size: Up to 9 cm.

Life Expectancy: Normally two years.

Range: Northwest Territory of Canada south to Mexico, east of the Rocky Mountains. In Wyoming, widespread and common in smaller streams, many ponds and some lakes east of the Continental Divide. Has been introduced into the Green River drainage.

Preferred Habitat: Cool and warm water, slow-flowing, weedy streams and shallow lakes and ponds. Common in many intermittent streams.

Feeding Habits: Primarily herbivorous, including algae, plankton and organic detritus. Also small numbers of insects.

Spawning Habits: In more northerly climates, individuals reach sexual maturity at one year of age; however, in Iowa, it was found that fish hatched in May reach adult size and were spawning by late July. Spawning activity normally begins in spring or early summer when water temperatures reach 16°C. Males select and guard nests located in rocky or weedy areas (also under logs) of pools in one to three feet of water. Females then deposit up to 12,000 adhesive eggs which cling

to the roof of the nest. The incubation period ranges from four to six days. During this phase of development, the male guards the eggs and agitates the water in the near vicinity of them. This agitation prevents silt accumulations, removes metabolic products and aerates the eggs.

Comments: At the study sites in June, 1976, examination of adult fish revealed that most spawning activity had already occurred, although several individuals, still gravid, were collected. This species serves as an excellent forage fish throughout the U. S.

Carp (Cyprinus carpio). (From: Baxter and Simon, 1970; Scott and Crossman, 1973.)

Adult Size: Seldom over 4.5 kilograms in Wyoming.

Life Expectancy: Up to 20 years.

Range: Throughout U. S. In Wyoming, common at lower elevations in all river systems except the Snake and Niobrara rivers.

Preferred Habitat: Lakes, lagoons and quiet pools and backwaters of rivers.

Feeding Habits: Omnivorous. Species "roots" in bottom muds for insects, annelids, molluscs, crustaceans and vegetation.

Spawning Habits: Maturity is normally reached in three to four years for males, while for females, four to five years.

Spawning occurs in the spring and early summer when water temperatures range from 17°C to 28°C in the shallow, weedy areas of pools. Carp are extremely prolific, with large females capable of producing up to several million adhesive eggs. No nests are built and no parental care is exhibited.

Eggs are scattered over the bottom where they adhere to vegetation and incubate for three to six days before hatching.

Comments: During the June, 1974, sampling on the Little Powder, no gravid individuals were collected. Two explanations can be offered for this; either spawning had already occurred, or the three individuals captured had not yet reached sexual maturity. Only one immature specimen was captured in 1975 on each study stream and none were collected in 1976. This species is normally considered detrimental to game fish because their "rooting" while feeding increases turbidity and destroys vegetation.

Flathead Chub (Hybopsis gracilis). (From: Baxter and Simon, 1970; Olund and Cross, 1961; Cross, 1967; Scott and Crossman, 1973.)

Adult Size: Average 13 cm to 18 cm. Up to 25 cm or more.

Life Expectancy: Several years.

Range: From the Northwest Territory of Canada south to Oklahoma and New Mexico. In Wyoming, common in all drainages east of the Continental Divide except the Madison, Yellowstone, Niobrara and South Platte river systems.

Preferred Habitat: Larger silty rivers. Seldom found in lakes and ponds.

Feeding Habits: Primarily carnivorous, including terrestrial and aquatic insects and small fish. Also some vegetation.

Spawning Habits: Species apparently spawns relatively late in summer when rivers are lower, warmer and the bottom more stable. No other information is available except that males become tuberculate in late summer, indicating the approach of breeding season.

Comments: Two of the four individuals collected from the Little Powder in June 1974 were females in pre-spawning condition.

Ripe females were collected in June 1975 on Antelope Creek.

Longnose Dace (Rhinichthys cataractae). (From: Baxter and Simon, 1970; Kuehn, 1949; Simpson, 1941; McPhail and Lindsey, 1970; Scott and Crossman, 1973.)

Adult Size: Average 8 cm to 10 cm. Up to 15 cm.

Life Expectancy: Up to five years.

Range: Throughout U. S. In Wyoming, native to and common in all drainages but the Green and Little Snake River basins.

Preferred Habitat: Both small and large streams in riffle areas.

Also found in lakes along rocky shorelines.

Feeding Habits: Primarily insectivorous, but also feed on small amounts of algae.

Spawning Habits: Spawning occurs in the spring and summer most probably in riffle areas over a gravel bottom. Each female normally produces from 200 to 1,200 adhesive eggs which cling to the substrate. No nest is built but one parent remains in the vicinity of egg deposition to guard them. At 16°C, eggs hatch in seven to ten days.

Comments: None of the fish collected were found to be gravid, indicating that spawning had already occurred or that the specimens were juvenile fish. Few individuals were collected during June 1975 sampling and none in 1976, most probably due to the lack of gravel bottomed riffle areas which this species prefers.

White Sucker (Catostomus commersoni). (From: Baxter and Simon, 1970; Reighard, 1920; Simpson, 1941; Scott and Crossman, 1973; Campbell, 1935; Geen et al., 1966.)

Adult Size: Rarely over 0.9 kilograms in Wyoming.

Life Expectancy: Up to 17 years.

Range: Rocky Mountains east to Atlantic seacoast and south from the Arctic Circle to southeastern U. S. In Wyoming, most common fish east of the Continental Divide. Also introduced into Green and Little Snake River drainages.

Preferred Habitat: Common in a variety of habitats, from high mountain lakes to sluggish lowland streams. Avoids fast current.

Feeding Habits: Omnivorous. Feeds along stream bottom primarily for insects, but also for algae and other organic debris.

Spawning Habits: Individuals normally mature from three to four years of age. Spawning activity begins in spring and early summer when water temperatures reach 10°C in shallow water over sand or gravel substrates. During spawning the males become densely tuberculate. There is no deliberate construction of a nest but the activities of the adults create depressions in the substrate into which the female may deposit up to 50,000 eggs. The incubation period lasts approximately 14 days.

Comments: In June, it appeared spawning had already occurred as no gravid adults were collected. This species serves as a good forage fish.

Northern Redhorse (Moxostoma macrolepidotum). (From: Baxter and Simon, 1970; Scott and Crossman; Meyer, 1962; Reed, 1962.)

Adult Size: Up to 51 cm and one kilogram.

Life Expectancy: Reported up to 12 years.

Range: Montana and Saskatchewan east to Atlantic seacoast and south to Oklahoma. In Wyoming, species had previously been collected in the North Platte and lower Laramie Rivers, in the Belle Fourche, Tongue and Powder River drainages, and in the Big Horn River.

Preferred Habits: Medium sized streams and lakes with cool, clear water.

Spawning Habits: In Iowa, individuals have been reported to become sexually mature at three years of age. Spawning occurs in the spring when water temperatures reach 11°C in shallow water over sand or gravel substrates. As with white suckers, there is no deliberate nest construction. Females produce up to 30,000 eggs, which are scattered over the stream bottom and then abandoned.

Comments: Of the five individuals collected in June, 1974, at the Little Powder River Site No. 2, none were gravid. As all were less than 13 cm in length, these were most probably juvenile fish. In 1975, one mature male in spawning colors was captured at Little Powder No. 1. None were collected in 1976.

River Carpsucker (Carpiodes carpio). (From: Baxter and Simon,

1970; Scott and Crossman, 1973; Harlan and Speaker, 1951; Deacon, 1961; Buchholz, 1957.)

Adult Size: Up to 4.5 kilograms in Wyoming.

Life Expectancy: Unknown.

Range: From Montana to Pennsylvania and south to Tennessee and Texas. In Wyoming, found in the Big Horn, Powder, Little Powder, Belle Fourche, and North Platte river basins.

Preferred Habitat: Quiet pools in clear and turbid streams, but not common in rubble-bottomed streams.

Feeding Habits: Primarily herbivorous, but also some small invertebrates.

Spawning Habits: Spawning occurs from April to June with the eggs being scattered over the stream bottom and left unattended.

Comments: During the June, 1974 sampling at Little Powder River Site No. 2 neither of the two individuals collected were gravid. Either spawning had previously occurred or these were juvenile forms (both were less than 15 cm in length). Neither of two 1975 fish collected were gravid.

Plains Killifish (Fundulus kansae). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Eddy and Underhill, 1974.)

Adult Size: Up to 10 cm.

Life Expectancy: Unknown.

Range: From Oklahoma to South Dakota, on the Great Plains. In Wyoming, primarily east of the Continental Divide. Present in the southeast corner of the state in the North and South Platte River drainages. Also present in the Cheyenne River

drainage, Ocean Lake, Owl Creek, and Big Horn River. Species is tolerant of water containing high values of total solids, primarily sulfates of magnesium and sodium.

Preferred Habitat: Warm water, sandy, shallow streams. Is tolerant to shifting sand bottoms, high salinities.

Feeding Habits: Feeds on surface, open water. Is primarily carnivorous, mostly small insects.

Spawning Habits: Spawning usually occurs in late summer, with water temperatures ranging near 28°C, over gravel in shallow water, 5 to 10 cm. Some Killifishes spawn throughout summer. Deposited eggs are buried, presumably from the shifting of sand.

Comments: An extremely hardy and aggressive species. Can be used as a bait fish, but not preferred. No gravid individuals found in June, 1975 or 1976.

Plains Minnow (Hybognathus placitus). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Eddy and Underhill, 1974.)

Adult Size: Up to 15 cm, usually 10.16 cm - 13 cm.

Life Expectancy: Unknown.

Range: The Great Plains, mainly west of the Missouri River from North Dakota and Montana south to central Texas. In Wyoming, found in the Big Horn, Tongue, Powder, Little Powder, Little Missouri, Belle Fourche and Cheyenne rivers. Is native to the North Platte River.

Preferred Habitat: Turbid side pools of silty streams, in slower water. Common associates are the flathead chub and river carpsucker.

Feeding Habits: Mainly herbivorous, but does include aquatic invertebrates in the diet.

Spawning Habits: Unknown for this species. Presumably eggs are scattered in silt-bottomed backwaters, with the breeding season apparently extended.

Comments: Ripe females were collected on Antelope Creek in June, 1975.

Stonecat (Noturus flavus). (From Baxter and Simon, 1970; Scott and Crossman, 1973.)

Adult Size: Up to 30 cm, but normally not more than 20 cm in Wyoming.

Life Expectancy: Individuals reported up to 9 years.

Range: Rocky Mountains east to New York and south to Alabama and Oklahoma. In Wyoming, found in the North Platte, Belle Fourche, Powder, Tongue and Big Horn drainages.

Preferred Habitat: Riffles or rapids of moderate to large streams having rubble bottoms. Also in lakes near sand and gravel bars where wave action is present.

Feeding Habits: Primarily carnivorous, feeding on immature aquatic insects. Secondarily, on molluscs, minnows, crayfish and plant material.

Spawning Habits: Peak activity in June and July, when water temperatures reach 28°C. Spawns in streams or shallow, rocky areas of lakes, depositing a mass of approximately 500 sticky eggs under the cobbles. Male guards the eggs.

Comments: Normally too small to be considered of value by sportsmen. Poison glands are well developed and can deliver

a painful sting. Only one specimen has thusfar been collected on the study streams, that being from the Little Powder River in June of 1976.

Largemouth bass (Micropterus salmoides). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Eddy and Underhill, 1974.)

Adult Size: 20-38 cm.

Life Expectancy: 13-15 years.

Range: From southern Canada and through the Great Lakes to Florida and northeastern Mexico. Has been introduced in Wyoming in the eastern counties, Little Thunder Basin Reservoir, the Lander area, and Festo Lake, near Wheatland.

Preferred Habitat: Larger lakes and backwaters of slow streams with summer temperatures exceeding 24°C and abundant beds of aquatic vegetation. With Wyoming's cool water temperatures, habitat is marginal for this species.

Feeding Habits: Carnivorous. Species feeds on insects, smaller fish, crayfish, and frogs.

Spawning Habits: Occurs when water temperatures reach 16-18°C, late spring to midsummer, in water 0.6 to 1.8 meters deep, on mud substrate or vegetation. Eggs are deposited in nests built by males which are rigorously defended until the eggs are hatched and the fry leave. The eggs must be protected from siltation or they will be deserted.

Comments: Species introduced into Reno Reservoir (located upstream from the study site) by the Wyoming Game & Fish Department. This undoubtedly is the source of the specimen collected.

Bluegill (Lepomis macrochirus macrochirus). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Eddy and Underhill, 1974.)

Adult Size: Up to 28 cm; but rarely over 18 cm in Wyoming.

Life Expectancy: 8-10 years.

Range: Native range is restricted to the fresh waters of eastern and central North America, from South Dakota to Lake Champlain, and south to Florida and Texas. Has been introduced in Wyoming and can be found in farm ponds in the northeastern counties. It is also found in Little Thunder Basin Reservoir, Campbell County, and Ocean Lake, Fremont County.

Preferred Habitat: Warm weedy ponds, sloughs, small lakes with deep weed beds, and sluggish streams.

Feeding Habits: Primarily carnivorous, feeding on insects, molluscs, smaller fish, and some plant material.

Spawning Habits: Spawning usually occurs from the last part of May to early July, with temperatures ranging from 68°C to 83°C. Substrates are sandy bottoms, mud, silt, or aquatic vegetation. Nests are built by aggressive and territorial males. Overpopulation of their habitat often occurs because these fish are prolific spawners.

Comments: Species introduced into Reno Reservoir (located upstream from the study site) by the Wyoming Game & Fish Department.

This undoubtedly is the source of the specimen collected.

Goldeye (Hiodon alosoides). (From: Baxter and Simon, 1970; Scott and Crossman, 1973; Kennedy and Sprules, 1967; Battle and Sprules, 1960; McPhail and Lindsey, 1970.)

Adult Size: Average 0.5 kg or less in Wyoming.

Life Expectancy: Individuals reported to 15 years.

Range: From Saskatchewan through the Missouri and Mississippi drainages east to Ohio and south to Tennessee, Oklahoma and Texas. In Wyoming, formerly found in the North Platte, Big Horn, Powder and Little Missouri river drainages. Found only in the lower Powder River, Clear Creek and Little Missouri River during recent collections.

Preferred Habitat: Quiet, turbid water of larger rivers, the small lakes, ponds and marshes connected to them, and also in muddy shallows of larger lakes. Large eyes adapt it to turbid conditions.

Feeding Habits: Carnivorous, including insects, fish and frogs. Juveniles feed primarily on zooplankton.

Spawning Habits: Spawning normally occurs in the pools of turbid rivers and backwater lakes and ponds during the spring and early summer when water temperatures reach the 10 to 13°C range. In Manitoba, females averaged 14,150 eggs each. Fertilized eggs are semi-buoyant and float in the current. Thus, no nest is built and no parental care is exhibited. Eggs hatch in about two weeks.

Comments: In Wyoming, young goldeye have never been collected and no data is available regarding spawning habits. Species are not classified as a game fish in Wyoming; however, in Canada it is considered a valuable food fish. One specimen was collected in the 1974 Little Powder River sampling, but none have been captured since.

Benthic Invertebrates

Little Powder River. The invertebrate fauna collected at the Little Powder sites were found to represent 3 phyla, 6 classes, 12 orders, 23 families and at least 33 genera. The taxonomic classification for these organisms is presented in Appendix A, Table A-1, while Tables A-2 and A-3 summarize the collections at each site.

Site No. 1

Throughout the 1976 sampling year, two taxa were found to predominate on a numbers basis at Site No. 1. In April and June, Dubiraphia (beetle) larvae comprised 27.9 and 28.6%, respectively, of total numbers, while in the fall and winter samples, Chironomidae larvae were most abundant (60.6 and 91.0%, respectively). Considering biomass, oligochaetes (April, 56.9%), freshwater snails (Lymnaea in June, 69.8%; Physa in September, 23.7%) and Chironomidae larvae (January, 76.2%) predominated at various times throughout the year. Another form sampled regularly was the mayfly nymph, Caenis. New taxa collected in 1976 were Sialis fuliginosa (alderfly larva), Gyraulus (snail), Neumania (water mite) and Belostoma (giant water bug).

Site No. 2

Invertebrate groups which predominated throughout the year on a numbers basis included Chironomidae larvae (April and January, 28.2 and 65.0%, respectively), Dubiraphia larvae (June, 26.8%) and oligochaetes (September, 28.7%). Physa, oligochaetes, Sphaerium (freshwater clam), Macromia (dragonfly nymph) and Chironomidae larvae were most abundant by weight at various times throughout the year. Caenis nymphs were also common. New genera collected in 1976 included Haliphus (beetle), Ptilostomis (caddisfly), Progomphus (dragonfly), Neumania and Gyraulus.

Overall Trends and Community Structure

Tables 7 and 8 present the abundance of bottom fauna collected at the two study sites in 1976 on both a numbers and a biomass per 0.1 square meter (m^2) basis.

As shown in Figure 8, the general trend in abundance is for lower numbers and biomass in the spring and early summer increasing to annual peak concentrations in the fall and winter. Also, it is of interest to note the greater fluctuations in abundance observed at Site #1 when compared with #2. Two interrelated hypotheses can be offered to explain these trends. First of all, as this reach of the Little Powder River is subject to periods of zero flow, it would appear likely that the invertebrate fauna has selected a life history strategy to cope with intermittency. This strategy involves overwintering in the late stages of larval development, followed by emergence of adult forms in the spring, coinciding with periods of runoff. The adults then reproduce and the availability of water at this time of year ensures both hatching success and distribution of the species.

The second hypothesis relates to the channel form and substrate characteristics of the two study sites. The channel in this reach of the Little Powder River through Thunder Basin can be categorized as incised or entrenched (a river which has cut its channel through the bed of the valley floor, its channel formed by the process of degradation; Arnett, 1976). At Site #1, the degree of entrenchment is greater than at #2, indicating that downcutting is more extensive (see photos in Figure 3). With more extensive erosion of the substrate at #1, a greater portion of the invertebrate fauna is being uprooted. Also, visual

TABLE 7

ABUNDANCE OF BOTTOM FAUNA ON A NUMBERS BASIS
AT THE TWO LITTLE POWDER RIVER STUDY SITES

Phylum	Class	Order	Numbers of Organisms per 0.1 m ²							
			Site No. 1				Site No. 2			
			April	June	September	January	April	June	September	January
Arthropoda	Insecta	Diptera	20.8	2.8	125.4	764.5	48.9	82.5	105.4	270.3
		Coleoptera	26.5	2.9	17.3	32.3	20.8	101.8	128.5	90.4
		Ephemeroptera	7.9	2.2	15.1	6.5	21.5	67.4	88.9	20.8
		Hemiptera	0.7	0	1.4	25.1	2.9	2.9	2.9	0.7
		Trichoptera	0.7	0	0	0	1.4	0	1.4	0
		Odonata	2.2	0	0.7	0	2.9	2.1	14.3	1.4
		Megaloptera	0	0	0.7	0	0	0	0	0
	Crustacea	Amphipoda	7.2	0.7	0	0	0	3.6	0	0
	Arachnoidea	Hydracarina	0	0	0.7	0	0	1.4	0	0
	Annellida	Clittellata	20.1	0.7	28.0	3.6	37.3	74.6	144.2	10.0
Mollusca	Gastropoda	Pulmonata	1.4	0.7	10.0	1.4	6.5	7.2	15.1	0.7
	Pelecypoda	Sphaeriacea	0	0	2.9	0	0.7	2.1	1.4	0
	TOTALS		87.5	10.0	202.2	833.4	142.9	345.6	502.1	394.3

TABLE 8

ABUNDANCE OF BOTTOM FAUNA ON A BIOMASS BASIS
AT THE TWO LITTLE POWDER RIVER STUDY SITES

Phylum	Class	Order	<u>Milligrams of Organisms per 0.1 m²</u>							
			Site No. 1				Site No. 2			
			April	June	September	January	April	June	September	January
Arthropoda	Insecta	Diptera	2.86	0.28	16.85	206.2	4.24	7.11	16.00	26.75
		Coleoptera	1.72	0.29	4.38	2.65	1.72	7.6	20.16	9.25
		Ephemeroptera	0.93	0.43	2.22	0.29	1.58	10.97	5.16	1.58
		Hemiptera	0.50	0	0.14	58.74	0.36	1.36	0.57	0.07
		Trichoptera	0.14	0	0	0	0.43	0	0.79	0
		Odonata	0.72	0	0.07	0	0.51	9.90	80.90	0.43
		Megaloptera	0	0	1.72	0	0	0	0	0
	Crustacea	Amphipoda	1.79	0.07	0	0	0	1.22	0	0
	Arachnoidea	Hydracarina	0	0	0.07	0	0	0.64	0	0
Annellida	Clittellata	Oligocheata	11.83	0.07	14.13	0.36	7.82	22.02	31.92	1.43
Mollusca	Gastropoda	Pulmonata	0.29	2.65	21.29	1.79	21.30	16.78	39.66	1.79
	Pelecypoda	Sphaeriacea	<u>0</u>	<u>0</u>	<u>2.87</u>	<u>0</u>	<u>3.59</u>	<u>29.76</u>	<u>18.00</u>	<u>0</u>
TOTALS			20.78	3.79	63.74	270.03	41.55	107.36	213.16	41.30

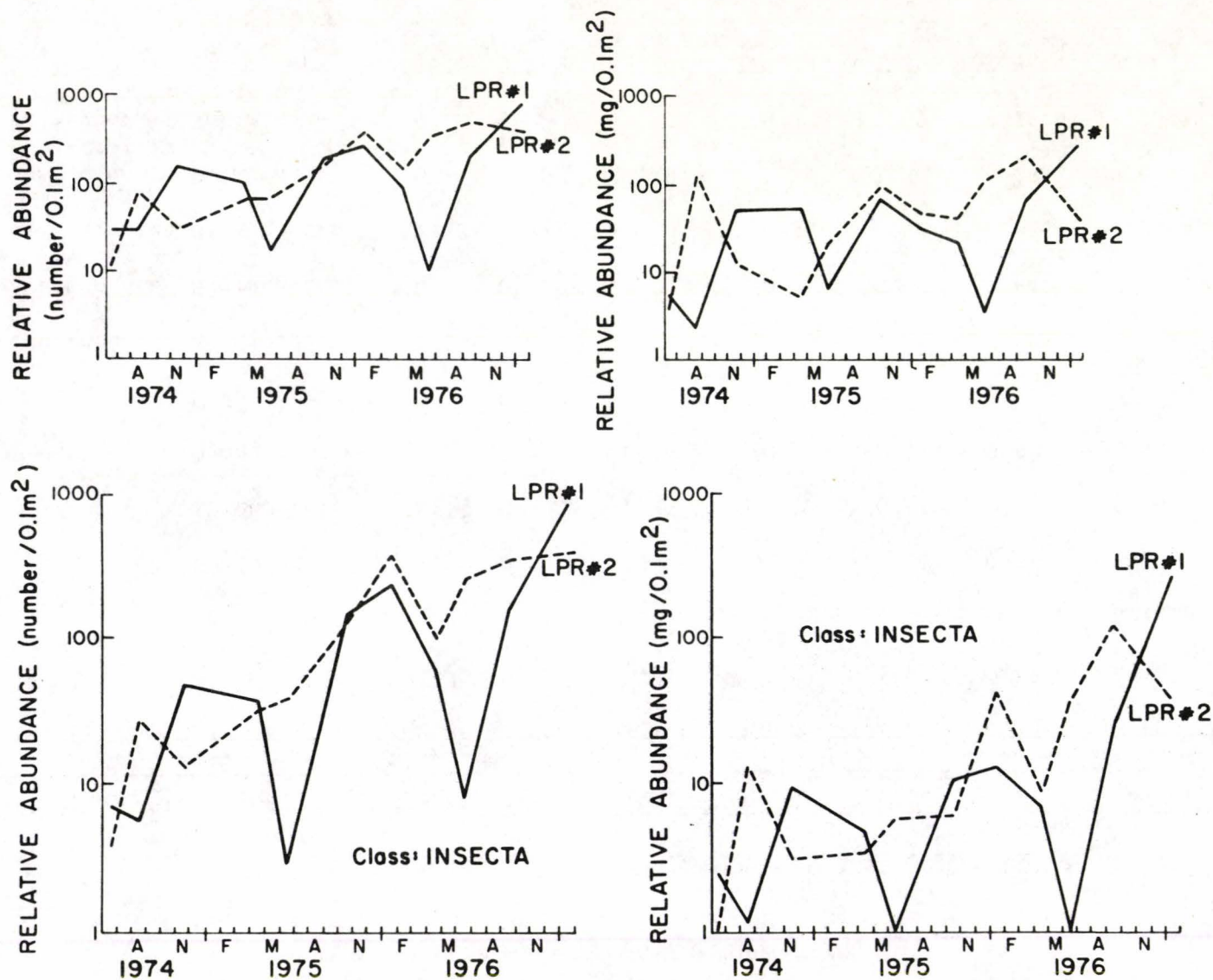


Figure 8. Seasonal Trends in Relative Abundance for All Invertebrates (including Insecta) and the Class Insecta Only for the Little Powder River Study Sites, 1974-1976.

observations of the substrate indicate a smaller overall particle size predominates at #1 than at #2. Thus, the substrate at #1 would be more susceptible to removal from the area, thereby disrupting the invertebrate community.

A summary of the relative abundance data for the 1976 Little Powder River bottom fauna collections (grouping both sites together) is provided in Table 9. Considering all samples, the most abundant invertebrate types on a numbers basis were Diptera larvae (56.4%), beetle larvae (16.7%), oligochaetes (12.6%) and mayfly nymphs (9.1%). These same 4 groups were also the predominant types in 1975. On a weight basis, Dipterans were again most abundant (36.8%), followed by snails (13.9%), nymphs of the order Odonata (12.1%) and oligochaetes (11.8%).

The trends observed in the Shannon-Weaver Diversity Index values for 1974 to 1976 at the two Little Powder sites are depicted in Figure 9. Inspection of these plots indicates a similar pattern as that seen for relative abundance. It would appear that the hypotheses presented above apply to the diversity variations also.

The results of Mann-Whitney and Kruskal-Wallis tests to determine differences in community diversity between the 1976 sampling times and sites are presented in Table 10, while Table 11 compares the 1975 and 1976 data. Analysis of these results provides verification of the above discussion regarding the greater seasonal variability observed in the benthic community at Site #1. Testing between sampling years generally indicates that no significant differences existed at the .01 level, although at Site #2 differences were found between the June 1975 and 1976 samples when considering diversity based upon invertebrate numbers.

TABLE 9

SUMMARY OF RELATIVE ABUNDANCE DATA FOR THE
BOTTOM FAUNA OF THE LITTLE POWDER RIVERNumbers and Milligrams per 0.1 m²

Phylum Class Order	April 1976				June 1976				September 1976				January 1977				Total			
	Mean No.	% Total	Mean Biomass (mg)	% Total	Mean No.	% Total	Mean Biomass (mg)	% Total	Mean No.	% Total	Mean Biomass (mg)	% Total	Mean No.	% Total	Mean Biomass (mg)	% Total	Mean No.	% Total	Mean Biomass (mg)	% Total
Arthropoda																				
Insecta																				
Diptera	34.9	30.2	3.55	11.4	42.7	24.0	3.70	6.7	115.4	32.7	16.43	11.9	517.4	84.3	116.48	74.8	710.4	56.4	140.16	36.8
Coleoptera	23.7	20.5	1.72	5.5	52.4	29.4	3.95	7.1	72.9	20.7	12.27	8.9	61.4	10.0	5.95	3.8	210.4	16.7	23.89	6.3
Ephemeroptera	14.7	12.7	1.26	4.0	34.8	19.5	5.70	10.3	52.0	14.8	3.69	2.7	13.7	2.2	0.94	0.6	115.2	9.1	11.59	3.0
Hemiptera	1.8	1.6	0.43	1.4	1.5	0.8	0.68	1.2	2.2	0.6	0.36	0.3	12.9	2.1	29.41	18.9	18.4	1.5	30.88	8.1
Trichoptera	1.1	1.0	0.29	0.9	0	0	0	0	0.7	0.2	0.40	0.3	0	0	0	0	1.8	0.1	0.69	0.2
Odonata	2.6	2.3	0.62	2.0	1.1	0.6	4.95	8.9	7.5	2.1	40.49	29.2	0.7	0.1	0.22	0.1	11.9	0.9	46.28	12.1
Megaloptera	0	0	0	0	0	0	0	0	0.4	0.1	0.86	0.6	0	0	0	0	0.4	<0.1	0.86	0.2
Crustacea																				
Amphipoda	3.6	3.1	0.90	2.9	2.2	1.2	0.65	1.2	0	0	0	0	0	0	0	0	5.8	0.5	1.55	0.4
Arachnoidea																				
Hydracarina	0	0	0	0	0.7	0.4	0.32	0.6	0.4	0.1	0.04	<0.1	0	0	0	0	1.1	0.1	0.36	0.1
Annelida																				
Clitellata																				
Oligochaeta	28.7	24.8	9.83	31.5	37.7	21.2	11.05	19.9	86.1	24.4	23.03	16.6	6.8	1.1	0.90	0.6	159.3	12.6	44.81	11.8
Mollusca																				
Gastropoda																				
Pulmonata	4.0	3.5	10.80	34.6	4.0	2.2	9.72	17.5	12.6	3.6	30.48	22.0	1.1	0.2	1.79	1.4	21.7	1.7	52.79	13.9
Pelecypoda																				
Sphaeriacea	0.4	0.3	1.80	5.8	1.1	0.6	14.88	26.8	2.2	0.6	10.44	7.5	0	0	0	0	3.7	0.3	27.12	7.1
TOTALS	115.5	(100.0)	31.20	(100.0)	178.2	(100.0)	55.6	(100.0)	352.4	(100.0)	138.49	(100.0)	614.0	(100.0)	155.69	(100.0)	1260.1	(100.0)	380.98	(100.0)

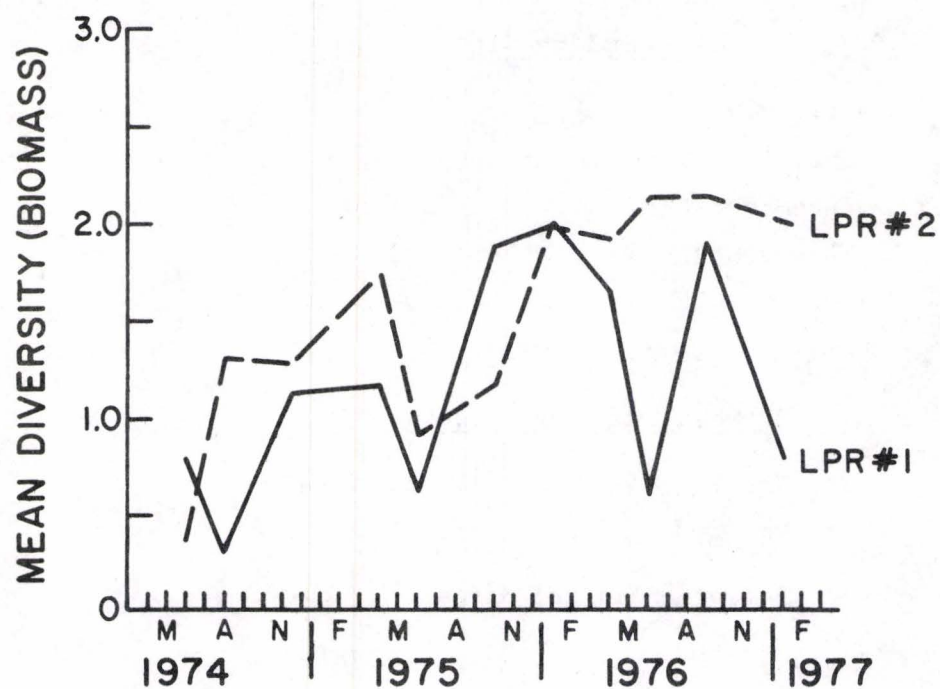
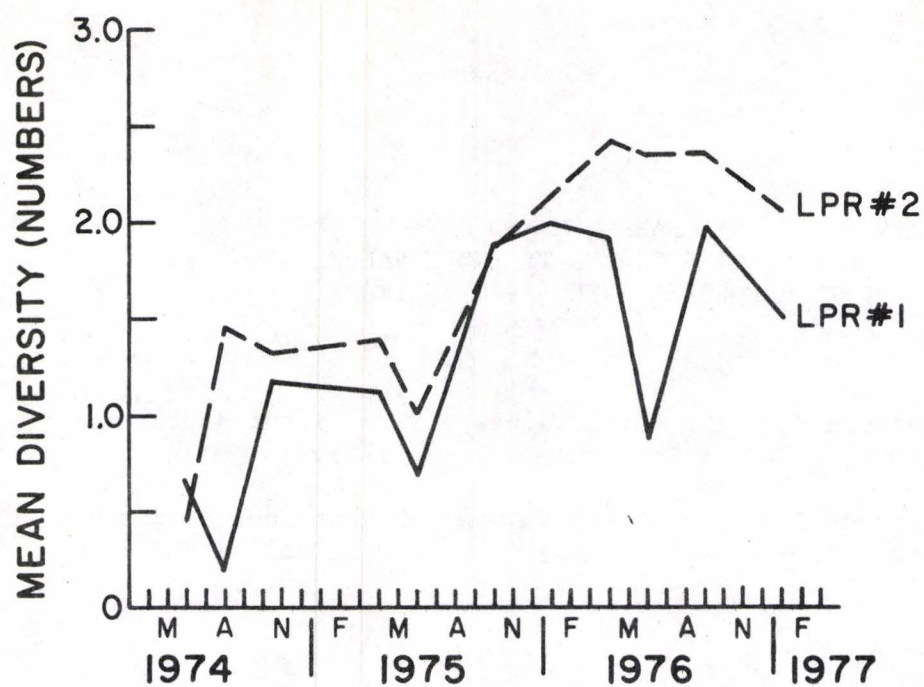


Figure 9. Seasonal Trends of Bottom Fauna Represented by Mean Shannon Diversity Index Values at the Little Powder River Study Sites in 1974-1977.

TABLE 10

RESULTS OF KRUSKAL-WALLIS RANK-SUM AND MANN-WHITNEY U TESTS
FOR SHANNON SPECIES DIVERSITY INDEX VALUES AT
LITTLE POWDER RIVER (1976) SITES

(Kruskal-Wallis) "Between Sampling Date" Values = Significant difference at
above 11.345 .01 level

(Mann-Whitney) "Between Sampling Sites" Values = Significant difference at
above 33.0 .01 level

NUMBERS BASIS

Between Sampling Dates

Site No. 1	9.067
Site No. 2	3.907

Between Sampling Sites

April, 1976	26.0
June, 1976	34.0
September, 1976	25.0
January, 1977	34.0

BIOMASS BASIS

Between Sampling Sites

Site No. 1	13.232
Site No. 2	1.713

Between Sampling Sites

April, 1976	22.0
June, 1976	36.0
September, 1976	28.0
January, 1977	36.0

TABLE 11

RESULTS OF MANN-WHITNEY TESTS FOR SHANNON SPECIES DIVERSITY
INDEX VALUES AT LITTLE POWDER RIVER SITES, 1975-1976

Values above 33.0 = Significant difference at .01 level

Values above 29.0 = Significant difference at .05 level

NUMBERS BASIS

Between LPR #1: 1975 and 1976

April	30.0
June	18.5
September-October	19.0
January	30.5

Between LPR #2: 1975 and 1976

April	33.0
June	34.0
September-October	26.0
January	20.0

BIOMASS BASIS

Between LPR #1: 1975 and 1976

April	26.0
June	26.0
September-October	30.0
January	30.0

Between LPR #2: 1975 and 1976

April	20.0
June	29.0
September-October	30.0
January	21.0

Antelope Creek. The benthic invertebrates collected at the Antelope Creek study sites in 1976 were found to represent 3 phyla, 6 classes, 12 orders, 24 families and at least 34 genera (Appendix B, Table B-1). This compares closely with the 3 phyla, 6 classes, 13 orders, 22 families and at least 29 genera identified in the 1975 samples. A summary of the bottom fauna collected at each site is presented in Tables B-2 and B-3. Due to heavy ice cover associated with very low water levels, these sites could not be sampled in January, 1977.

Site No. 1

Freshwater snails (primarily Physa and Lymnaea) predominated at Site #1 throughout the year on both a numbers and a biomass basis. This group accounted for from 26.9 (September) to 58.0% (April) of the numbers collected and contributed up to 63.4% (April) on a weight basis. Other taxa which commonly appeared in the samples included freshwater clams (Pisidium), freshwater shrimp (Hyallela azteca), Chironomid larvae, and mayfly nymphs (Caenis).

Site No. 2

Chironomidae larvae predominated throughout the sampling year at Site #2, comprising from 30.8 (June) to 66.5% (September) of the numbers collected. Considering biomass, Physa was most abundant at all sampling times, ranging from 25.0 (June) up to 83.0% (April) of the total. Other common forms taken throughout the year included the Dipteran larva, Palpomyia, Pisidium, Caenis, Chironomid pupa, and oligochaetes. It was these same taxa which predominated during the 1975 sampling year.

Overall Trends and Community Structure

Tables 12 and 13 present the abundance of bottom fauna

TABLE 12

ABUNDANCE OF BOTTOM FAUNA ON A NUMBERS BASIS
AT THE TWO ANTELOPE CREEK STUDY SITES

Phylum	Class	Order	Numbers of Organisms per 0.1 m ²					
			Site No. 1			Site No. 2		
			April	June	September	April	June	September
Arthropoda	Insecta	Diptera	86.0	126.9	539.9	23.6	3.6	87.4
		Coleoptera	7.8	2.9	56.6	0	0	0
		Ephemeroptera	12.9	9.3	464.0	0	0.7	26.5
		Odonata	5.0	0.7	135.5	0	0.7	0.7
		Trichoptera	10.0	0	7.9	0	0	0
		Hemiptera	0	0	2.9	0	0	0.7
	Crustacea	Amphipoda	28.0	17.9	989.0	0	0.7	0
Annelida	Arachnoidea	Hydracarina	0	0	7.9	0	0	0
	Clittellata	Oligocheata	12.2	20.1	28.0	3.6	0.7	0.7
		Hirudinea	0	0.7	5.7	0	0	0
Mollusca	Gastropoda	Pulmonata	527.1	465.4	999.8	0.7	1.4	1.4
	Pelecypoda	Sphaeriacea	<u>220.2</u>	<u>246.7</u>	<u>482.7</u>	<u>0</u>	<u>1.4</u>	<u>0</u>
TOTALS			909.2	890.6	3719.9	27.9	9.2	117.4

TABLE 13

ABUNDANCE OF BOTTOM FAUNA ON A BIOMASS BASIS
AT THE TWO ANTELOPE CREEK STUDY SITES

Phylum	Class	Order	<u>Milligrams of Organisms per 0.1 m²</u>					
			<u>Site No. 1</u>			<u>Site No. 2</u>		
			<u>April</u>	<u>June</u>	<u>September</u>	<u>April</u>	<u>June</u>	<u>September</u>
Arthropoda	Insecta	Diptera	10.04	25.76	7.38	2.57	0.43	2.8
		Coleoptera	6.18	1.72	38.43	0	0	0
		Ephemeroptera	1.58	2.01	4.88	0	0.07	1.14
		Odonata	1.58	0.14	83.84	0	0.29	0.07
		Trichoptera	4.09	0	3.15	0	0	0
		Hemiptera	0	0	5.09	0	0	0.07
	Crustacea	Amphipoda	3.23	1.22	57.89	0	0.07	0
Annellida	Arachnoidea	Hydracarina	0	0	0.71	0	0	0
	Clittellata	Oligocheata	2.51	5.74	1.86	0.86	0.07	0.07
		Hirudinea	0	3.66	42.25	0	0	0
Mollusca	Gastropoda	Pulmonata	1662.54	887.97	2506.46	16.85	0.50	8.10
	Pelecypoda	Sphaeriacea	<u>933.51</u>	<u>520.62</u>	<u>1633.21</u>	<u>0</u>	<u>0.29</u>	<u>0</u>
TOTALS			2625.26	1448.84	4385.15	20.28	1.72	12.25

collected at the two Antelope Creek sites on a numbers and biomass per 0.1 m^2 basis, while Table 14 summarizes these data by sample dates. Trends in relative abundance and diversity for the 1975-1976 period are plotted on Figures 10 and 11. Tables 15 and 16 present the results of statistical comparisons of diversity between sampling sites, dates and years.

As found in 1975, the densest concentrations of bottom fauna were collected at Site No. 1, where abundance ranged from 890.6 up to 3719.9 organisms per 0.1 m^2 . At No. 2, numbers varied only from 9.2 up to 117.4 per 0.1 m^2 . Several inter-related explanations can be offered for this variation between sites. Site No. 2 is located much lower in the basin than is No. 1 and as such is influenced by the contributions of additional tributary streams. These tributaries, following extended precipitation events, add not only flow to Antelope Creek, but also large quantities of sediment. Inspection of these drainages, as well as Antelope Creek itself between No. 1 and No. 2, indicates that mass wasting is a common occurrence. The resultant effect is best illustrated by certain of the measurements taken on June 24, 1976 at the two study sites. Following several days of rain in the basin, flow at No. 1 was 2.2 cfs and the water was clear (turbidity of 1.3 NTU, secchi disc still visible at the deepest location, 1.3 feet). On the same day, flow at No. 2 was measured at 24.0 cfs, while turbidity was 450 NTU and a secchi disc reading of 0.1 feet was recorded. The presence of rooted aquatic vegetation at No. 1, while absent at No. 2, is also indicative of a more stable substrate and typically less turbid water conditions. The inter-relation of these factors then is most likely the explanation for the greater abundance of invertebrate fauna

TABLE 14

SUMMARY OF RELATIVE ABUNDANCE DATA FOR THE
BOTTOM FAUNA OF ANTELOPE CREEKNumbers and Milligrams per 0.1 m²

Phylum	Class	Order	April				June				September				Total			
			Mean No.	% Total	Mean Bio- mass (mg)	% Total	Mean No.	% Total	Mean Bio- mass (mg)	% Total	Mean No.	% Total	Mean Bio- mass (mg)	% Total	Mean No.	% Total	Mean Bio- mass (mg)	% Total
96 Arthropoda	Insecta	Diptera	54.8	11.7	6.31	0.5	65.3	14.5	13.10	1.8	313.7	16.3	5.09	0.2	433.8	15.3	24.50	0.6
		Coleoptera	3.9	0.8	3.09	0.2	1.5	0.3	0.86	0.1	28.3	1.5	19.22	0.9	33.7	1.2	23.17	0.5
		Ephemeroptera	6.5	1.4	0.79	0.1	5.0	1.1	1.04	0.1	245.3	12.8	3.01	0.1	256.8	9.0	4.84	0.1
		Odonata	2.5	0.5	0.79	0.1	0.7	0.2	0.22	<0.1	68.1	3.5	41.96	1.9	71.3	2.5	42.97	1.0
		Trichoptera	5.0	1.1	2.05	0.2	0	0	0	0	4.0	0.2	1.58	<0.1	9.0	0.3	3.63	<0.1
		Hemiptera	0	0	0	0	0	0	0	0	1.8	0.1	2.58	0.1	1.8	0.1	2.58	<0.1
	Crustacea	Amphipoda	14.0	3.0	1.62	0.1	9.3	2.1	0.65	0.1	494.5	25.8	28.95	1.3	517.8	18.2	31.22	0.7
	Arachnoidea	Hydracarina	0	0	0	0	0	0	0	0	4.0	0.2	0.36	<0.1	4.0	0.1	0.36	<0.1
Annelida	Clittellata	Oligocheata	7.9	1.7	1.69	0.1	10.4	2.3	2.91	0.4	14.4	0.8	0.97	<0.1	32.7	1.2	5.57	0.1
		Hirudinea	0	0	0	0	0.4	0.1	1.83	0.3	2.9	0.2	21.13	1.0	3.3	0.1	22.96	0.5
Gastropoda	Pulmonata		263.9	56.3	839.70	63.5	233.4	51.9	444.24	61.3	500.6	26.1	1257.28	57.2	997.9	35.2	2541.22	59.8
Pelecypoda	Sphaeriacea		<u>110.1</u>	<u>23.5</u>	<u>466.76</u>	<u>35.3</u>	<u>124.1</u>	<u>27.6</u>	<u>260.46</u>	<u>35.9</u>	<u>241.4</u>	<u>12.6</u>	<u>816.61</u>	<u>37.1</u>	<u>475.6</u>	<u>16.8</u>	<u>1543.83</u>	<u>36.4</u>
TOTALS			468.6	(100.0)	1322.8	(100.0)	450.1	(100.0)	725.31	(100.0)	1919.0	(100.0)	2198.74	(100.0)	2837.7	(100.0)	4246.85	(100.0)

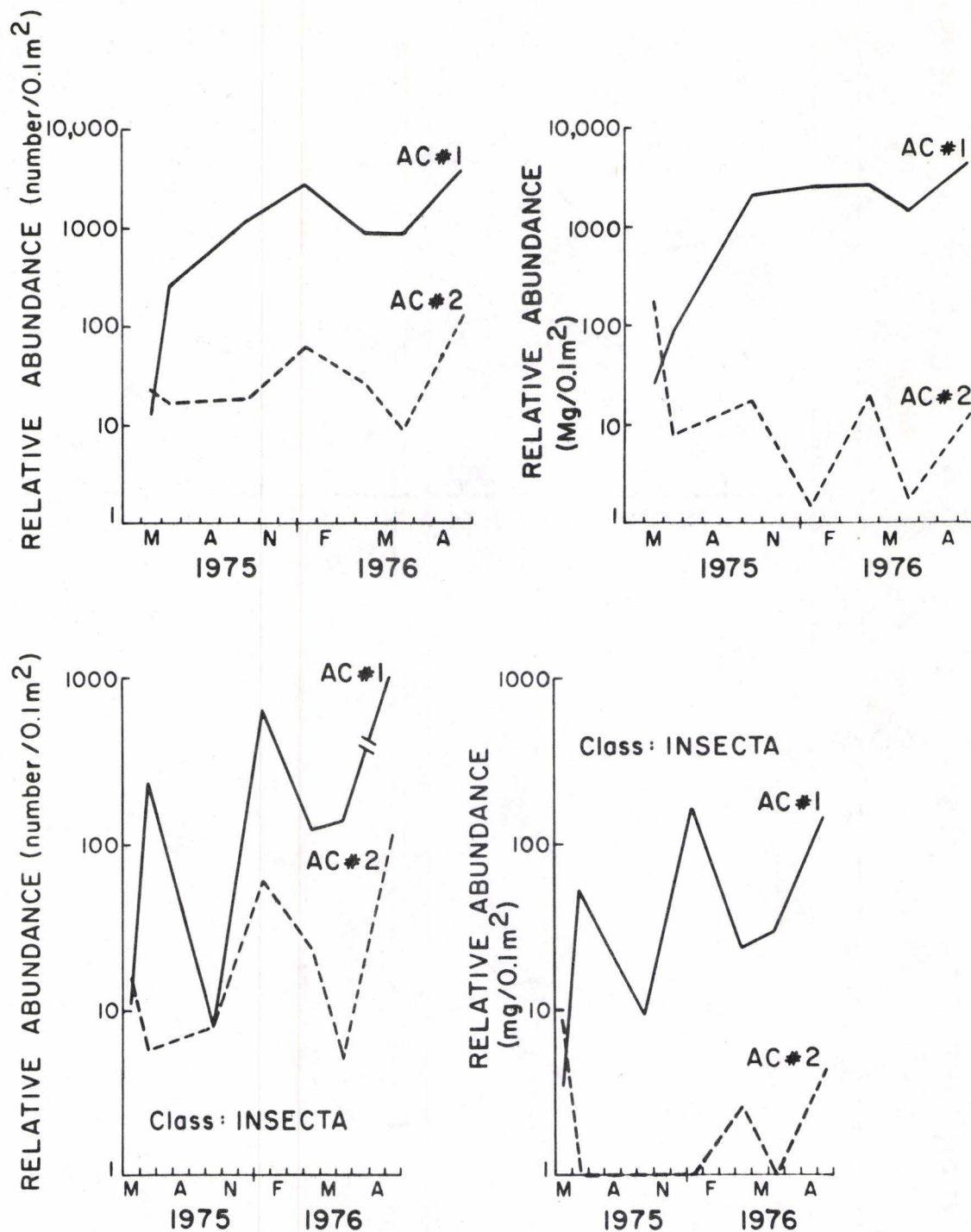


Figure 10. Seasonal Trends in Relative Abundance for All Invertebrates (including Insects) and Insects only for the Antelope Creek Study Sites, 1975 and 1976.

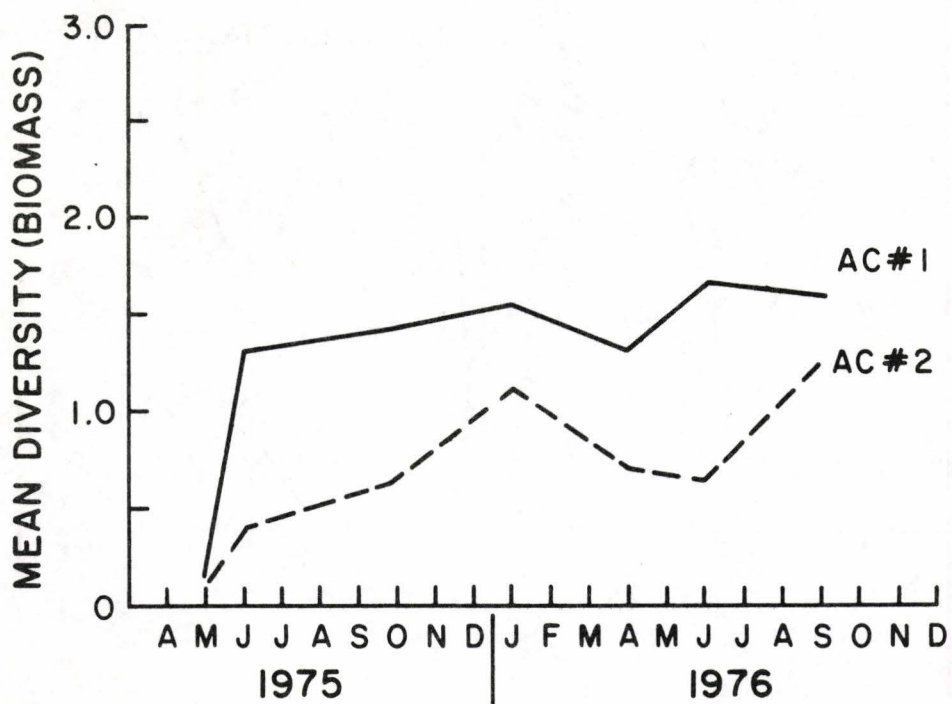
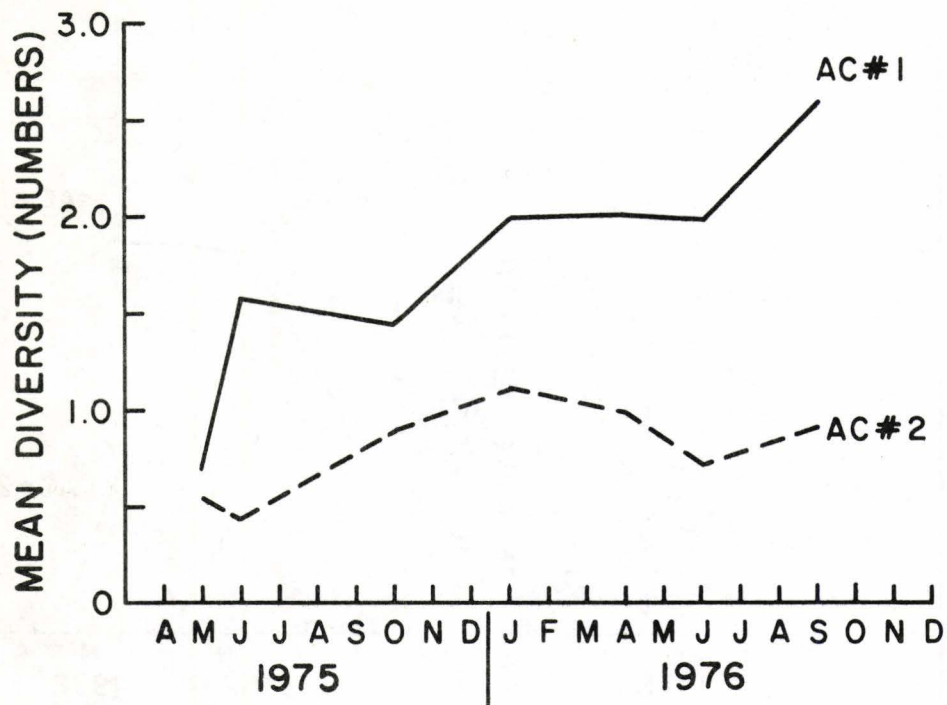


Figure 11. Seasonal Trends of Bottom Fauna Represented by Mean Shannon Diversity Index Values at the Antelope Creek Study Sites in 1975 and 1976.

TABLE 15

RESULTS OF KRUSKAL-WALLIS RANK-SUM AND MANN-WHITNEY U TESTS
FOR SHANNON SPECIES DIVERSITY INDEX VALUES AT
ANTELOPE CREEK SITES (1976)

(Kruskal-Wallis) "Between Sampling Date" Values = Significant difference at
above 9.210 .01 level

(Mann-Whitney) "Between Sampling Site" Values = Significant difference at
above 33.0 .01 level

NUMBERS BASIS

Between Sampling Dates

Site No. 1	5.240
Site No. 2	2.403

Between Sampling Sites

April, 1976	32.0
June, 1976	36.0
September, 1976	35.0

BIOMASS BASIS

Between Sampling Dates

Site No. 1	3.266
Site No. 2	4.683

Between Sampling Sites

April, 1976	31.0
June, 1976	36.0
September, 1976	26.0

TABLE 16

RESULTS OF MANN-WHITNEY TESTS FOR SHANNON SPECIES DIVERSITY
INDEX VALUES AT ANTELOPE CREEK SITES, 1975-1976

Values above 33.0 = Significant difference at .01 level

Values above 29.0 = Significant difference at .05 level

NUMBERS BASIS

Between AC #1: 1975 and 1976

April	36.0
June	26.0
September	36.0

Between AC #2: 1975 and 1976

April	21.0
June	25.0
September	24

BIOMASS BASIS

Between AC #1: 1975 and 1976

April	36.0
June	22.0
September	24.0

Between AC #2: 1975 and 1976

April	22.0
June	31.5
September	27.0

at Site No. 1.

Inspection of the abundance plots in Figure 10 indicates no clear seasonal trends thusfar in our studies on Antelope Creek. It is unfortunate that heavy ice conditions (18 inches thick) associated with very low water levels prevented sampling in January of 1977.

Considering diversity of the benthic communities (Figure 11), the same relationship between the two sites was found as that observed for abundance. At all sampling times, diversity values ranged higher at No. 1 than at No. 2. Cause for this undoubtedly parallels that given above for abundance. While the results of the statistical tests (Table 15) indicate no significant differences in diversity between 1976 sampling dates at each site, significant differences were found at the .01 level between the two sites in both June and September. Testing at the .01 level between sampling years (1975-1976) showed no significant differences at Site 2, while for Site 1, differences were found between both the April and the September samplings.

School Creek-Little Thunder Creek. 1976 was the first year that sampling was conducted on these ephemeral Thunder Basin streams. For School Creek, our collections included representatives of 3 phyla, 5 classes, 10 orders, 22 families and at least 29 genera (Appendix C, Table C-1). Members of at least 34 genera were sampled from Little Thunder Creek (Table C-2). Summaries of the collections made at these sites are presented in Tables C-3 and C-4.

School Creek

The bottom fauna of School Creek was found to be predominated by an assortment of freshwater snails, including Physa, Lymnaea, and Gyraulus. On a numbers basis, these genera accounted for up to 92.9%

(May) of the individuals collected, while for biomass, they contributed between 96.4 (January) and 99.3% (June) of the total. Other taxa which constituted at least 1.0% of the numbers or biomass at one time or another throughout the year included Chironomid larvae (Chironomus and Pentaneura), caddisfly larvae (Limnephilus), and oligochaetes.

Little Thunder Creek

Freshwater snails also predominated the invertebrate fauna of Little Thunder Creek. In addition to Physa, Gyraulus, and Lymnaea, another snail, Ferrissia, was also collected. On a numbers basis, these 4 genera contributed from 70.2 (January) to 92.6% (June) of the totals, while they provided up to 97.8% (June) of the biomass. Other common groups included Chironomid larvae, beetle larvae (Dubiraphia), mayfly nymphs (Caenis) and freshwater shrimp (Hyallela azteca).

Overall Trends and Community Structure

Relative abundance data for School and Little Thunder Creeks are presented in Tables 17 and 18, while Figures 12 and 13 illustrate the seasonal trends observed in abundance and diversity. The results of statistical tests of diversity values between the sample dates and sites are presented in Table 19.

The relative abundance of organisms at these study sites showed little seasonal fluctuation. This was due primarily to the predominance of the snail groups which spend their entire life cycle in the aquatic habitat. For this reason, separate plots were made for the class Insecta, a group in which most representatives spend at least a portion of their life cycle out of the water (typically, the adult stages for reproductive functions). Thus, greater seasonal variation is seen when only Insecta is considered. Generally, the trend would appear to be

TABLE 17
SUMMARY OF RELATIVE ABUNDANCE DATA FOR THE
BOTTOM FAUNA OF SCHOOL CREEK

Phylum Class Order	May 1976				June 1976				September 1976				January 1977				Total			
	Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean		Mean	
	No.	% Total	Biomass (mg)	% Total	No.	% Total	Biomass (mg)	% Total	No.	% Total	Biomass (mg)	% Total	No.	% Total	Biomass (mg)	% Total	No.	% Total	Biomass (mg)	% Total
Arthropoda																				
Insecta																				
Diptera	3.6	0.3	5.81	<0.1	10.0	0.8	14.20	0.2	184.4	14.8	46.54	1.0	82.4	43.2	78.75	3.5	280.4	7.2	145.3	0.6
Coleoptera	4.9	0.4	2.85	<0.1	5.7	0.5	2.22	<0.1	59.6	4.8	19.50	0.4	0.7	0.4	0.43	<0.1	70.9	1.8	25.0	0.1
Ephemeroptera	0.7	<0.1	0.07	<0.1	0		0		17.2	1.4	0.65	<0.1	0		0		17.9	0.5	0.72	<0.1
Trichoptera	15.7	1.3	92.45	0.7	0		0		0		0		0		0		15.7	0.4	92.45	0.4
Hemiptera	0.7	<0.1	0.07	<0.1	0		0		0		0		0		0		0.7	<0.1	0.07	<0.1
Odonata	0		0		1.4	0.1	2.51	<0.1	4.3	0.4	0.14	<0.1	0		0		5.7	0.2	2.65	<0.1
Crustacea																				
Amphipoda	1.4	<0.1	0.43	<0.1	0		0		63.8	5.1	20.58	0.5	0		0		65.2	1.7	21.01	<0.1
Annelida																				
Clitellata																				
Oligochaeta	61.0	4.9	16.35	0.1	113.3	9.4	27.83	0.4	28.0	2.2	6.67	0.1	0.7	0.4	0.07	<0.1	203.0	5.2	50.92	0.2
Mollusca																				
Gastropoda																				
Pulmonata	1166.9	92.9	12844.05	99.1	1070.7	89.1	6432.14	99.3	884.2	71.0	4512.99	97.8	106.8	56.0	2189.69	96.5	3228.6	82.9	25978.87	98.7
Pelecypoda																				
Sphaeriacea	0.7	<0.1	0.93	<0.1	0		0		3.6	0.3	5.45	0.1	0		0		4.3	0.1	6.38	<0.1
TOTALS	1255.6	(100.0)	12963.01	(100.0)	1201.1	(100.0)	6478.9	(100.0)	1245.1	(100.0)	4612.52	(100.0)	190.6	(100.0)	2268.94	(100.0)	3892.4	(100.0)	26323.37	(100.0)

TABLE 18

SUMMARY OF RELATIVE ABUNDANCE DATA FOR THE
BOTTOM FAUNA OF LITTLE THUNDER CREEK

	May 1976				June 1976				September 1976				January 1977				Totals			
	Mean No.	% Total No.	Mean Biomass (mg)	% Total Biomass	Mean No.	% Total No.	Mean Biomass (mg)	% Total Biomass	Mean No.	% Total No.	Mean Biomass (mg)	% Total Biomass	Mean No.	% Total No.	Mean Biomass (mg)	% Total Biomass	Mean No.	% Total	Mean Biomass (mg)	% Total Biomass
Diptera	908.6	18.8	229.22	5.3	24.4	0.5	56.01	1.0	17.2	0.4	2.50	<0.1	607.5	11.6	32.99	0.8	1557.7	8.1	320.72	1.7
Coleoptera	56.7	1.2	5.74	0.1	156.3	3.3	9.54	0.2	209.5	4.7	23.82	0.6	52.4	1.0	7.32	0.2	474.9	2.5	46.42	0.3
Ephemeroptera	203.0	4.2	14.99	0.3	53.8	1.1	16.07	0.3	366.5	8.3	39.88	0.9	248.2	4.7	26.90	0.6	871.5	4.5	97.84	0.5
Hemiptera	0		0		0		0		0.7	<0.1	0.14	<0.1	0		0		0.7	<0.1	0.14	<0.1
Odonata	33.0	0.7	10.97	0.3	6.4	0.1	17.93	0.3	28.0	0.6	3.37	<0.1	53.8	1.0	29.48	0.7	121.2	0.6	61.75	0.3
Trichoptera	0		0		0		0		0		0		15.1	0.3	95.75	2.2	15.1	<0.1	95.75	0.5
Amphipoda	140.6	2.9	12.69	0.3	83.2	1.8	5.31	0.1	148.5	3.4	11.55	0.3	576.6	11.0	62.04	1.4	948.9	4.9	91.59	0.5
Hydracarina	3.6	<0.1	2.15	<0.1	1.4	<0.1	0.22	<0.1	1.4	<0.1	0.14	<0.1	0.7	<0.1	0.07	<0.1	7.1	<0.1	2.58	<0.1
Oligocheata	16.5	0.3	1.65	<0.1	12.9	0.3	1.86	<0.1	0.7	<0.1	0.29	<0.1	5.7	0.1	0.50	<0.1	35.8	0.2	4.30	<0.1
Hirudinea	0		0		0		0		0.7	<0.1	5.67	0.1	0.7	<0.1	1.08	<0.1	1.4	<0.1	6.75	<0.1
Pulmonata	3472.6	71.7	4030.44	93.4	4363.5	92.6	5635.84	97.9	3636.9	82.3	4193.19	97.4	3670.7	70.1	4037.27	93.9	15143.7	78.8	17896.74	95.8
—	0		0		0.7	<0.1	0.29	<0.1	0		0		0		0		0.7	<0.1	0.29	<0.1
Sphaeriacea	8.6	0.2	7.24	0.2	8.6	0.2	14.42	0.3	11.5	0.3	25.53	0.6	5.7	0.1	6.45	0.2	34.4	0.2	53.64	0.3
TOTALS	4843.2	(100.0)	4315.09	(100.0)	4711.2	(100.0)	5757.49	(100.0)	4421.6	(100.0)	4306.09	(100.0)	5237.1	(100.0)	4299.85	(100.0)	19213.1	(100.0)	18678.51	(100.0)

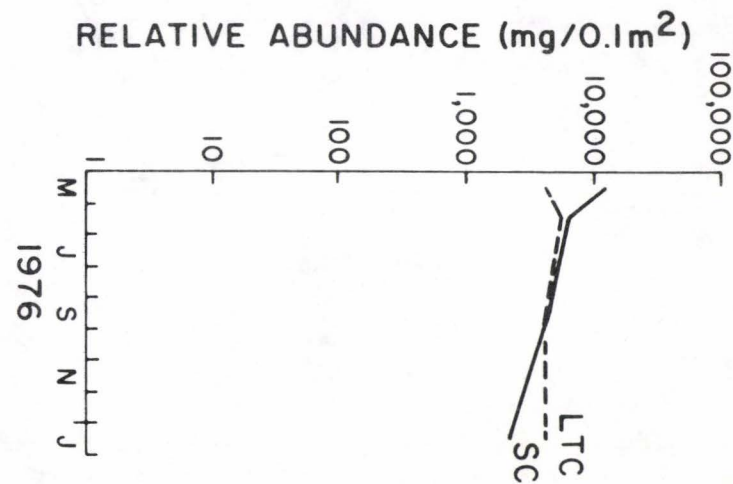
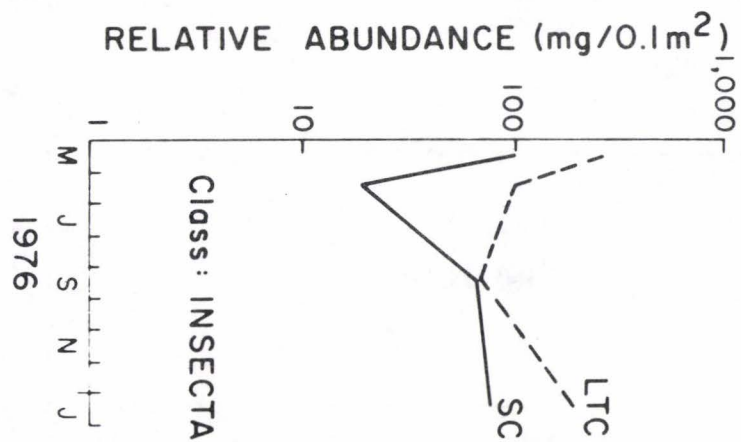
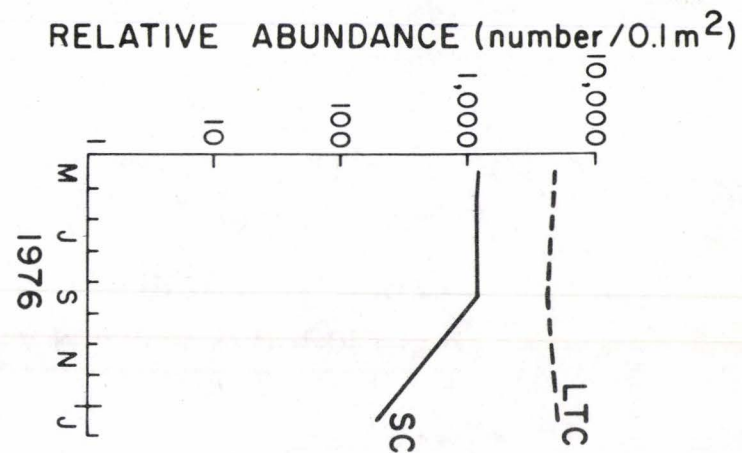
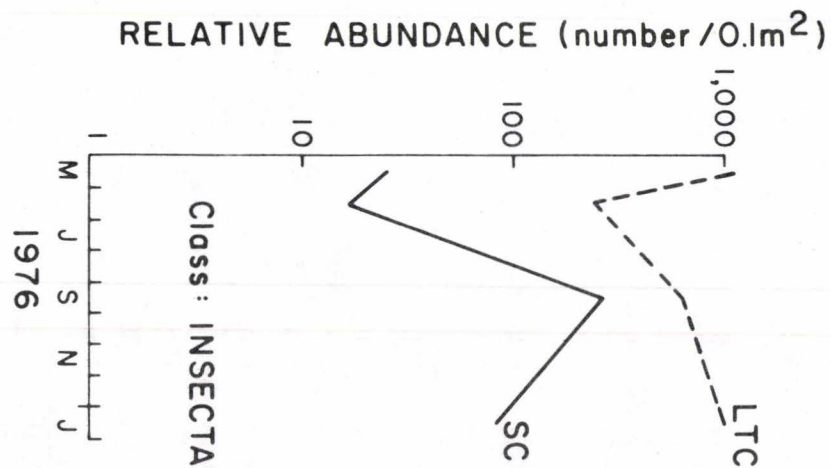


Figure 12. Seasonal Trends in Relative Abundance of All Invertebrates (including Insects) and for Only the Class Insecta at the School Creek and Little Thunder Creek Study Sites in 1976-1977.

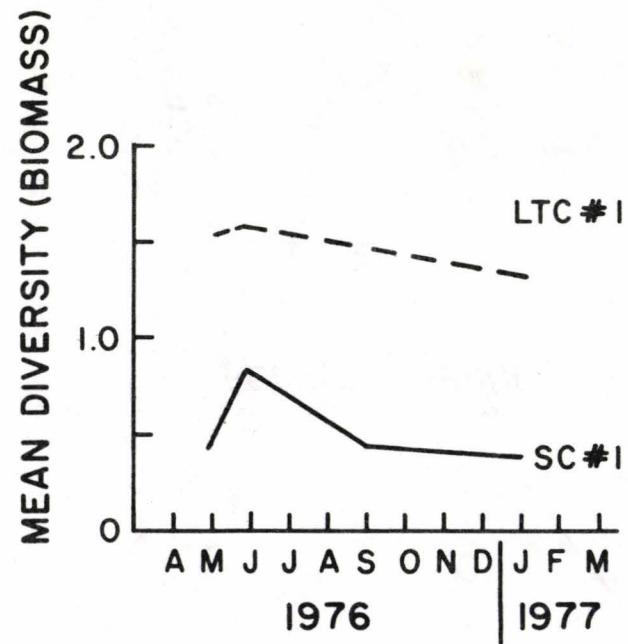
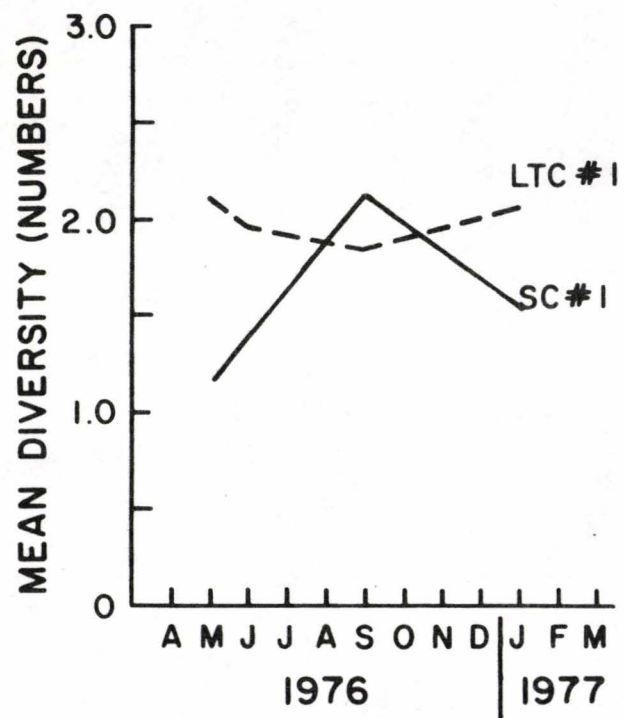


Figure 13. Seasonal Trends of Bottom Fauna Represented by Mean Shannon Diversity Index Values at the School Creek and Little Thunder Creek Sites in 1976-1977.

TABLE 19

RESULTS OF KRUSKAL-WALLIS RANK-SUM AND MANN-WHITNEY U TESTS
FOR SHANNON SPECIES DIVERSITY INDEX VALUES AT
SCHOOL CREEK AND LITTLE THUNDER CREEK (1976)

(Kruskal-Wallis) "Between Sampling Date" Values = Significant difference at
above 11.345 at .01 level

(Mann-Whitney) "Between Sampling Site" Values = Significant difference at
above 33.0 .01 level

NUMBERS BASIS

Between Sampling Dates

Site - School Creek	13.347
Site - Little Thunder Creek	2.930

Between Sampling Sites

May, 1976	35.0
June, 1976	32.0
September, 1976	28.0
January, 1977	35.0

BIOMASS BASIS

Between Sampling Dates

Site - School Creek	3.073
Site - Little Thunder Creek	0.720

Between Sampling Sites

May, 1976	36.0
June, 1976	36.0
September, 1976	36.0
January, 1977	36.0

toward lowest densities in the early summer increasing into the fall and winter quarters. Possibly the survival strategy discussed above for the Little Powder River explains this fluctuation. Support for this hypothesis is provided by noting that for the most abundant insect order, the Diptera, 14 of the 17 pupae collected throughout the year were sampled in May. This indicates the emergence of the adult stages was soon to occur.

Generally, diversity of the benthic community ranged higher on Little Thunder than on School Creek, especially on a biomass basis (Figure 13, Table 19). Considering seasonal variation, the only significant difference found was for School Creek diversity based upon numbers. Biomass diversity showed little fluctuation between seasons.

Water Quality

Water quality results are reported on WRRI laboratory sheets for each of the sites sampled. The site number and dates of sampling are included below. Data sheets may be found in Appendix D.

Little Powder River

Site 1	4-28-76
Site 2	4-28-76
Site 1	6-23-76
Site 2	6-23-76
Site 1	9-23-76
Site 2	9-23-76
Site 1	1-20-77
Site 2	1-20-77

Antelope Creek

Site 1	4-28-76
Site 2	4-28-76
Site 1	6-24-76
Site 2	6-24-76
Site 1	9-22-76
Site 2	9-22-76
Site 1	1-19-77
Site 2	Not Sampled

Little Thunder Creek

Single Site	5-13-76
Single Site	6-24-76
Single Site	9-22-76
Single Site	1-19-77

School Creek

Single Site	5-13-76
Single Site	6-24-76
Single Site	9-22-76
Single Site	1-19-77

These data are summarized in Appendix E, Tables E-1 to E-4, while Tables E-5 to E-8 present the maximum, minimum and expected range of each constituent. At this time the expected range column is only an estimate. Heavy precipitation or extended drought prior to sampling could cause these values to fall outside the expected limits. In comparing data it is best to use the actual values determined through sampling.

The tentative conclusions offered following last year's sampling program can still be considered valid with the additional year's data at Antelope Creek and the Little Powder River. These waters are highly buffered, moderately alkaline, and contain high concentrations of calcium, magnesium, sodium, bicarbonate and sulfate. These waters are suitable only for the most restrictive uses. Wyoming water quality standards and suggested EPA water quality criteria have been tabularized and can be found in Appendix F. Comparisons of these data will give approximate uses for the sampled resources. It must be added that the criteria list is only intended to provide general guidance. There is a dilution effect between sampling sites on the Little Powder River while a sizable concentration is observed between Antelope Creek sites. This suggests that added flow of lesser chemical concentration is introduced to the Little Powder River drainage between sampling stations while either evaporative concentration or concentrative inflow is occurring in the sampled reach of Antelope Creek. By site, these and the other sampled waters could be generally categorized in the following manner.

Little Powder River

- Total salt concentrations at both sites for 3 of the 4 sampling dates would prove restrictive to almost all uses.
- High suspended solids values noted at both sites during the June sampling period. This is typical of the mainstem of the Powder River and has been observed in previous years.

- A downstream dilution effect is observed for total ions which is most notable in terms of calcium, magnesium and sulfate concentrations. This suggests that dilution water between sampling stations is higher in relative terms, in sodium and bicarbonate.
- Two samples (April and June) at site 2 exceed the "threshold concentration" of 0.1 mg/l for zinc. Additionally, total iron found at both sites in June would exceed recommended criteria for aquatic life.
- Sharp increases in boron concentrations were observed during September and January sampling at both sites. This should continue to be monitored if future mine reclamation revegetation plans were to be dependent upon these waters or the parent materials, as boron is toxic to certain plant species.
- Measurable ammonia and Kjeldahl nitrogen levels in April and June samples indicating that non-point contribution is present.
- Good continuity with previous data.

Antelope Creek

- Increasing mineralization in a downstream direction. No significant change is observed in chemical relationships between sites indicating that the factors influencing concentration are constant throughout the study area.
- Low levels of trace metals and elements.
- Low COD levels.
- High suspended solids concentrations found at site 2 in June. In that low background levels were observed at site 1 during this same period it must be assumed that significant erosion potential exists in the reach between sites. If this area were ever surface mined special soil and overburden treatments might prove necessary to retard erosion.
- Generally strong similarities to other drainages in the area and to previous data.

Little Thunder Creek

- Generally better water quality than that observed at the other streams. The waters, though still exceeding user criteria for salinity, have a lower dissolved solids concentration than at the other sampling stations.
- Low organic levels.
- Low nutrient levels.

- Well buffered, alkaline waters.
- January sample exhibited greater boron concentrations than expected.
- Zinc, in May, exceeded the "threshold concentration."
- Low total and dissolved iron concentrations.
- Exceptionally low levels for the other trace metals and elements.

School Creek

- The most saline of the waters sampled. The most dilute sample exceeds the recommended level for agricultural use by three times.
- Exceptionally hard, these waters would prove almost useless to those industrial applications where scale formation is a problem.
- Inordinately high boron levels observed during the September and January sampling periods. These levels would restrict agricultural applications.
- Exceptionally high manganese levels. Discoloration of vessels and other containers holding these waters could be expected.
- Higher total and dissolved iron than that recommended for preservation of aquatic life was observed in over fifty percent of the samples (refer to Appendix F).
- Excess zinc was observed in a single sample.
- In general these waters are by far the worst in overall quality. Total salinity combined with several other elements found in toxic concentrations would preclude these waters being used in almost any economic application.

CHAPTER V

DISCUSSION

The aquatic fauna of the four Thunder Basin study streams can generally be classified as primarily warmwater forms, tolerant of a wide range of environmental conditions. These are low-gradient, shallow, sluggish habitats, characterized by vast fluctuations in flow (0 to 453 m³/sec (16,000 cfs) on the Cheyenne River below Antelope Creek #2 and 0 to 28.3 m³/sec (1000 cfs) on the Little Powder), temperature (0 to 30°C), turbidity (up to 1500 NTU measured in 1974 on the Little Powder), and dissolved oxygen (down to 2.2 mg/l on School Creek in January, 1977). Also, these waters are quite saline (TDS measured up to 9760 mg/l at School Creek) and were periodically found to contain high concentrations of heavy metals, primarily zinc.

Considering the harsh environmental extremes mentioned above, it is not surprising that the study streams provide little potential as sport fisheries. The black bullhead and green sunfish which comprise the predominant game fish populations are neither present in large numbers nor, for the most part, in catchable sizes. Analysis of the water quality data, in conjunction with the hydrologic observations made, indicate that the fishery potential at the Little Thunder site exceeds that for the other study sections. While zero flow was observed here in September, it is apparent that ground water feeds this reach as little fluctuation in water level was observed throughout the year. Hasfurther and Rechard (1976) report an evaporation rate of 142 cm per year for shallow ponds in the Gillette area. Thus, were it

not for ground water inflow, greater fluctuations would be expected on Little Thunder, much like that observed on School Creek in September, when the site was almost completely dewatered.

Water quality conditions on Little Thunder were also found to be the most favorable for aquatic fauna. Dissolved oxygen concentrations were never found to drop below 5.4 mg/l while the pH ranged from 8.0 to 8.6. Fry (1960) concluded that good fish production was generally achieved in a pH range of 6.7 to 8.6. Little Thunder water was found to be relatively clear at all sample times, as indicated by the turbidity measurements (all less than 63 NTU) and secchi disc readings (0.2 to 0.8 m). The abundance of rooted aquatic vegetation was also indicative of clear water conditions. Salinity ranged lower at the Little Thunder site (TDS of 738 to 1670 mg/l) than at the other study sections, also indicating more favorable conditions for fish life. It is proposed that seining efforts on Little Thunder Creek be increased during 1977 to better determine the abundance and size range of the largemouth bass and bluegill known to be present.

Two species of particular interest thusfar collected on the Little Powder River are the goldeye and the stonecat. Goldeye are currently on the Wyoming Game and Fish Department's list of rare and endangered wildlife (status undetermined). While only one specimen has been collected to date (1974), it is important that the Little Powder does provide some of the last habitat for the species in the state.

Increasing attention has of late been paid to the stonecat, especially in the Northern Great Plains area. With rising demands for water by industry and other users, fisheries biologists have become concerned with the problem of determining suitable instream flow

regimes to maintain the fishery resources of the region. Bovee (1975) has recommended that the stonecat be used as the indicator species for recommending such flows for rearing habitat. This designation as an indicator was based upon two criteria: 1) the species has a very narrow range of physical habitat requirements for rearing, primarily in regard to velocity and sedimentation; and 2) it is naturally present in many streams of the region.

For the reasons given above, it is our recommendation that during 1977 concentrated efforts should be made to determine the abundance of these two species on Thunder Basin lands and to investigate their life histories, food preferences and, to the extent possible, their general habitat preferences.

The benthic invertebrate fauna of the four Thunder Basin study streams during 1976 was predominated by freshwater snails (Physa, Lymnaea and Gyraulus were found at all 4), Diptera larvae (Family Chironomidae), mayfly nymphs (Caenis), beetle larvae (primarily Dubiraphia), freshwater shrimp (Hyallela azteca), clams (Sphaerium and Pisidium), oligochaetes (Family Tubificidae) and damselfly nymphs (primarily Ischnura). This list closely approximates that of our 1975 studies on just Antelope Creek and the Little Powder, and would most probably cover the major types expected on any of the streams throughout Basin lands.

This assemblage of invertebrates can be characterized as forms commonly found living in or near the mud substrates of ponds, lakes and streams where organic debris is available as a food source (Usinger, 1973; Hynes, 1970; Pennak, 1953). Typically, these types are tolerant of a wide range of environmental conditions, including

intermittency, high temperatures and turbidities, low dissolved oxygen, high TDS concentrations, and low habitat diversity in terms of substrate, water depths and velocities.

Throughout the sampling year, relative abundance of the bottom fauna generally ranged higher at School Creek, Little Thunder Creek and Antelope Creek No. 1. This was due primarily to the dense stands of aquatic vegetation at these sites and the abundance of snails associated with them. As shown in an earlier section, turbidity measurements ranged lower at these three study sections and secchi disc readings higher, the result being increased light penetration and photosynthetic activity.

Mean annual diversity (average for all samples taken at a given site throughout the year) was found to be highest at Little Powder #2 (2.30 for numbers; 2.07 for biomass), Antelope Creek #1 (2.23 numbers, 1.54 biomass) and Little Thunder Creek (2.00 numbers; 1.54 biomass). Values for the remaining 3 sites were as follows: Little Powder #1 (1.57 numbers; 1.26 biomass); School Creek (1.57 numbers; 0.51 biomass); and, Antelope Creek #2 (1.06 numbers; 0.88 biomass).

Mangum (1975) states that in macroinvertebrate communities, it is natural to find a few species with high numbers of individuals and many species with a few individuals. The effects of an unfavorable condition are often manifest by elimination of some species, a reduction in numbers of other species, and/or an increase in numbers of one to several species which proliferate due to an absence of competition and an abundance of food. Through his work, Mangum has developed the following stream classification system based upon Shannon-Weaver index values:

Diversity IndexStream Condition

3-4

Excellent

2-3

Good

1-2

Fair

<1

Poor

Applying this system to our six study sites using the mean annual diversity values based on numbers, stream condition would be rated as follows:

SiteStream Condition

Little Powder #1

fair

Little Powder #2

low-good

Antelope #1

low-good

Antelope #2

low-fair

School Creek

fair

Little Thunder Creek

low-good; high-fair

From our sampling and analysis program to date, it appears we are beginning to define the range of diversity values which can be expected for the benthic communities in the various types of aquatic habitats associated with the stream environments of Thunder Basin. Overall, values can be expected to vary from approximately 1.0 up to 2.5. A tentative classification by habitat type would be as follows:

Habitat Type
Expected Location
Within Diversity Range
(1.0-2.5)

Permanent, clear-water pool on ephemeral or
intermittent stream (Little Thunder Creek and
Antelope Creek #1)

Upper half

Ephemeral pool on ephemeral stream (School Creek)

Lower half

Permanent, turbid water pool on intermittent
stream (Antelope Creek #2)

Lower half

Turbid water pool in severely incised reach of
perennial stream (Little Powder #1)

Lower half

Turbid water pool of perennial stream less severely
incised with lateral erosion occurring (Little
Powder #2)

Upper half

To emphasize, this is offered as a tentative classification, based on general characteristics of our study streams and sites. Another year of sampling and observation on these streams will allow us to 1) improve our estimate for the diversity range; 2) verify or refute the relationship between the diversity range and the habitat type descriptions; 3) provide more accurate descriptions of the habitat types; and 4) through more extensive fish sampling, explore the possibility of adding a "fisheries factor" of some type to the classification system.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

Fisheries

The sport fishery potential of the four Thunder Basin study streams is quite limited due to the environmental extremes discussed in previous sections. Black bullhead and green sunfish are the predominant game fish species, with bluegill, largemouth bass and stonecat also being collected at specific sites. Due to its stable water levels and water quality conditions, the Little Thunder Creek site has the greatest potential for development of a sport fishery. Non-game fish species present consist primarily of an assemblage of minnow species.

More extensive fish sampling efforts are recommended for 1977. Not only will this provide more information on the species composition, relative abundance and population size for all of the study streams, it will allow us to assess the distribution, life history patterns and food habits of the more critical species, such as the goldeye and stonecat of the Little Powder River and the largemouth bass of Little Thunder Creek.

Benthic Invertebrate Fauna

Results of our sampling indicate that the following list would most likely include the major invertebrate types expected from any of the streams throughout Thunder Basin: snails (Physa, Lymnaea, Gyraulus), mayfly nymphs (Caenis), beetle larvae (primarily Dubiraphia), shrimp (Hyalalela azteca), clams (Sphaerium and Pisidium), oligochaetes and damselfly nymphs (primarily Ischnura). Based upon the Shannon-Weaver

diversity index values and the classification used by Mangum (1975), the general condition of Thunder Basin streams can be rated as from low-fair up to low-good. Dependent upon the habitat type, we would expect diversity values for these benthic communities to range from approximately 1.0 to 2.5. A tentative classification of habitat types, based upon observable water quality, channel form and flow regime characteristics, has been proposed in relation to their location within this diversity range.

Another year of bottom fauna sampling is recommended to allow us to better define these habitat types and the expected diversity range within each type. We anticipate that development of such a classification system will prove useful to agency personnel involved in environmental assessment.

Water Quality

The data reported in this document for the Little Powder River and Antelope Creek exhibit strong similarities to the data previously collected at these sites. The tentative conclusions offered last year appear valid when examined with the more current data. These waters, while appearing too salty for all but the most limited applications, can be considered "typical" of surface water found in the Eastern Powder River Basin.

The data reported for Little Thunder and School Creeks are the first findings in this investigation. Generally, they too could be considered to be "typical" of the region's waters. These two sites however, represent the extremes of what could be expected in the area's surface water quality. Little Thunder Creek, while containing waters more saline than that recommended for most uses, is probably of as good

a quality as is generally found in the area. Low levels of organics and trace metals would indicate that these waters could be capable of supporting much aquatic life.

School Creek, however, has salinity levels exceeding 25% sea water with concentrations in excess of recommended criteria for iron, zinc, manganese and boron. Some levels of retardation of indigenous aquatic life should be observed.

To provide background and support data for the continued sampling of the aquatic biota recommended above, it is our recommendation that this water quality program also be continued.

LITERATURE CITED

- American Public Health Association. 1975. Standard Methods for the Examination of Water and Waste Water. 14th ed. New York: American Public Health Association.
- Arnett, J. L. 1976. Nomenclature for Instream Assessments. U.S. Fish and Wildlife Service Report. 7 p.
- Battle, H. I. and W. M. Sprules. 1960. "A description of the semi-buoyant eggs and early development stages of the goldeye (Hiodon alosoides (Rafinesque)). Journal of the Fishery Resources Board Canada, XVII, 245-65.
- Baxter, George T. and James R. Simon. 1970. Wyoming Fishes. Bulletin No. 4. Cheyenne, Wyoming: Wyoming Game and Fish Department.
- Black, E. C. 1953. "Upper Lethal Temperatures of Some British Columbia Freshwater Fishes." Journal of the Fishery Resources Board Canada, X, 196-210.
- Bovee, Ken D. 1975. "The Determination, Assessment, and Design of 'Instream value' Studies for the Northern Great Plains Region." Report for the Northern Great Plains Resources Program, Denver, Colorado. 205 p.
- Buchholz, M. M. 1957. "Life History of the River Carpsucker (Carpoides c. carpio) in the Des Moines River, Iowa." Proceedings of the Iowa Academy of Sciences, LXIV, 589-600.
- Campbell, R. S. 1935. "A Study of the Common Sucker, Catostomus commersoni (Lacépède) of Waskesiu Lake." M.S. Thesis, University of Saskatchewan, Saskatoon, Saskatchewan.
- Carlander, K. D. 1969. Handbook of Freshwater Fishery Biology. Vol. I: Life History Data on Freshwater Fishes of the United States and Canada, Exclusive of the Perciformes. Ames, Iowa: Iowa State University Press.
- Chorley, Richard J. (ed.). 1969. Introduction to Fluvial Processes. London: Methuen and Co., Ltd.
- Corbett, D. M. 1962. Stream-Gaging Procedures. U.S. Geological Survey Water-Supply Paper No. 888. Washington, D.C.: Government Printing Office.

- Cross, F. B. 1967. Handbook of Fishes of Kansas. University of Kansas Museum of Natural History Miscellaneous Publication No. 45. Lawrence, Kansas: University of Kansas.
- Deacon, J. E. 1961. "Fish Populations, Following a Drought, in the Neosho and Marias des Coygues Rivers of Kansas." University of Kansas Publications of the Museum of Natural History, XIII, 361-427.
- De Lury, D. B. 1947. "On the Estimation of Biological Populations," Biometrics, III, 145-157.
- De Lury, D. B. 1951. "On the Planning of Experiments for the Estimation of Fish Populations." Journal of the Fishery Resources Board Canada, VIII, 281-307.
- Dixon, W. J. and F. J. Massey, Jr. 1969. Introduction to Statistical Analysis. New York: McGraw-Hill Book Co. 638 p.
- Eddy, S. and J. C. Underhill. 1974. Northern Fishes. 3rd ed. Minneapolis: University of Minnesota Press. 414 p.
- Environmental Protection Agency. 1973. Biological Field and Office Methods. EPA Report 670/4-73-001.
- Environmental Protection Agency. 1974. Manual of Methods for Chemical Analysis of Water and Wastes. EPA Report 625/6-74-003. 298 p.
- Forney, J. L. 1955. "Life History of the Black Bullhead, Ameiurus melas (Rafinesque) of Clear Lake, Iowa." Iowa State College Journal of Science, XXXI, 145-162.
- Fry, F. E. J. 1960. "Requirements for the Aquatic Habitat." Pulp and Paper Magazine of Canada, LXI, T.62-T.66.
- Geen, G. H., T. G. Northcote, G. F. Hartman, and C. C. Lindsey. 1966. "Life Histories of Two Species of Castostomid Fishes in Sixteen-mile Lake, British Columbia, With Particular Reference to Inlet Spawning." Journal of the Fishery Resources Board Canada, XXIII, 1761-1788.
- Harlan, J. R. and E. B. Speaker. 1951. Iowa Fish and Fishing. Des Moines: Iowa Conservation Commission.
- Hasfurther V. and P. A. Rechard. 1976. "Hydrology". Chapter VII in Final Environmental Assessment, Black Thunder Mine Site - Volume II.
- Hunter, J. R. 1963. "The Reproductive Behavior of the Green Sunfish, Lepomis cyanellus." Zoologica, XLVIII, 13-24.
- Hynes, H. B. N. 1970. The Ecology of Running Waters. Toronto: University of Toronto Press.
- Kennedy, W. A. and W. M. Sprules. 1967. Goldeye in Canada. Fishery Resources Board Canada Bull. 161.

- Kuehn, Jerome H. 1949. "A Study of a Population of Longnose Dace (Rhinichthys c. cataractae)."
Proceedings of the Minnesota Academy of Sciences, XVII, 81-87.
- Mangum, Fred A. 1975. "Analysis of Macroinvertebrate Samples from Ten Rocky Mountain Streams." Ph.D. Dissertation. Brigham Young University. 245 p.
- Markus, H. C. 1934. "Life History of the Blackhead Minnow (Pimephales promelas)."
Copeia, III, 116-122.
- McPhail, J. D. and C. C. Lindsey. 1970. Freshwater Fishes of Northwestern Canada and Alaska.
Fishery Resources Board Canada Bull. 173.
- Meyer, W. H. 1962. "Life History of Three Species of Redhorse (Moxostoma) in the Des Moines River, Iowa." Transactions of the American Fishery Society, XV, 412-419.
- Minckley, W. L. 1973. Fishes of Arizona. Phoenix, Arizona: Sims Printing Co., Inc.
- Odum, Eugene P. 1971. Fundamentals of Ecology. 3rd ed. Philadelphia: W. B. Saunders Company.
- Olund, L. J. and F. B. Cross. 1961. "Geographic Variation in the North American Cyprinid Fish, Hybopsis gracilis." University of Kansas Publication of the Museum of Natural History, XIII, 323-348.
- Parker, M. 1976. "Limnology". Chapter VIII in Final Environmental Assessment, Black Thunder Mine Site - Volume II.
- Pennak, R. W. 1953. Freshwater Invertebrates of the United States. New York: The Ronald Press Co.
- Person, H. T. 1939. "Water Resources of Missouri River Basin in Wyoming (Cheyenne River)." WPA Report to Wyoming State Engineer's Office. 51 p.
- Reed, E. B. 1962. Limnology and Fisheries of the Saskatchewan River in Saskatchewan. Fisheries Branch, Department of Natural Resources, Saskatchewan Fisheries Report No. 6.
- Reighard, J. 1920. "The Breeding Behavior of the Suckers and Minnows." Biological Bulletin, XXXVIII, 1-32.
- Scott, W. B. and E. J. Crossman. 1973. Freshwater Fishes of Canada. Fishery Resources Board Canada Bull. 184.
- Simpson, J. C. 1941. Food Analysis of Some Important Species of Wyoming Forage Fishes. M.S. Thesis, University of Wyoming, Laramie, Wyoming.
- Smith, Verne E., V. C. Pelton and S. A. Bender. 1976. Water Resources Data System. Water Resources Series No. 61. University of Wyoming. 136 p.

- Sokal, R. R. and F. J. Rohlf. 1969. Biometry. San Francisco: W. H. Freeman and Co. 776 p.
- Starrett, W. C. 1951. "Some Factors Affecting the Abundance of Minnows in the Des Moines River, Iowa." Ecology, XXXII, 13-27.
- U. S. Department of the Interior. 1974. Final Environmental Impact Statement: Eastern Powder River Coal Basin of Wyoming. Washington, D.C.: Government Printing Office.
- U. S. Department of the Interior. Geological Survey. Water Resources Data for Wyoming. Part 1. Surface Water Records. Washington, D.C.: Government Printing Office.
- Usinger, R. L., ed. 1973. Aquatic Insects of California. Berkeley: University of California Press.
- Walker, E. M. 1953. The Odonata of Canada and Alaska. University of Toronto Press. 292 p.
- Wallace, C. R. 1967. "Observations on the Reproductive Behavior of the Black Bullhead (Ictalurus melas)."
Copeia, IV, 852-853.
- Ward, H. B. and G. C. Whipple. 1959. Freshwater Biology. 2nd ed. New York: John Wiley & Sons, Inc. 1248 p.
- Welch, P. S. 1948. Limnological Methods. New York: McGraw-Hill Book Co.
- Wesche, T. A., R. Kerr, and D. Baldrige. 1975. "Aquatic Biota and Abiota of the Little Powder River in Thunder Basin National Grassland Wyoming." Water Resources Research Institute, University of Wyoming, Report to Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service.
- Wilhm, Jerry L. 1967. "Comparison of Some Diversity Indices Applied to Populations of Benthic Macroinvertebrates in a Stream Receiving Organic Wastes." Journal of the Water Pollution Control Federation, XXXIX, 1673-1683.
- Wilhm, Jerry T. and T. C. Dorris. 1968. "Biological Parameters for Water Quality Criteria." BioScience, XVIII, 477-481.
- Wynne-Edwards, V. C. 1932. "The Breeding Habits of the Black-Headed Minnow (Pimephales promelas Raf.)." Transactions of the American Fishery Society, LXII, 382-383.
- Wyoming Game and Fish Department. Wyoming's Rare and Endangered Wildlife. Cheyenne, Wyoming: Wyoming Game and Fish Department.

Appendix A

BOTTOM FAUNA OF LITTLE POWDER RIVER

TABLE A-1

TAXONOMIC CLASSIFICATION OF BENTHIC FAUNA FROM THE LITTLE POWDER RIVER

<u>Phylum</u>	<u>Class</u>	<u>Order</u>	<u>Family</u>	<u>Genus</u>
Arthropoda	Insecta	Diptera (two-winged flies)	Chironomidae	<u>Chironomus</u> sp. -- *
				<u>Pentaneura</u> sp.
			Ceratopogonidae	<u>Palpomyia</u> sp.
			Tabanidae	<u>Chrysops</u> sp. --
			--	--
		Coleoptera (beetles)	Elmidae	<u>Dubiraphia</u> sp.
			Halipilidae	<u>Halipilus</u> sp. --
			--	--
		Ephemeroptera (mayfly)	Caenidae	<u>Caenis</u> sp.
		Odonata (damselfly and dragonflies)	Coenagrionidae	<u>Ischnura</u> sp. --
				--
			Gomphidae	<u>Progomphus</u> sp. --
			Libellulidae	<u>Macromia</u> sp.
			Psychomyiidae	<u>Polycentropus</u> sp.
			Phryganeidae	<u>Ptilostomis</u> sp. --
			--	--
		Hemiptera (water bugs)	Corixidae	--
			Belostomatidae	--
			Dipsocoridae	--
			--	--
		Megaloptera (hellgrammites)	Sialidae	<u>Sialis fuliginosa</u>
	Crustacea	Amphipoda (shrimp)	Talitridae	<u>Hyallela azteca</u>
	Arachnoidea	Hydracarina (water mites)	Unionicolidae	<u>Neumania</u> sp.
			Limnocharidae	<u>Limnocharis</u> sp.
Annelida	Clitellata	Oligochaeta (worms)	Tubificidae	--
Mollusca	Gastropoda	Pulmonata (snails)	Physidae	<u>Physa</u> sp.
			Lymnaeidae	<u>Lymnaea</u> sp.
			Planorbidae	<u>Gyraulus</u> sp.
	Pelecypoda	Sphaeriacea (clams)	Sphaeriidae	<u>Sphaerium</u> sp. --
			--	--

*--indicates organism was unidentifiable at given taxonomic level.

TABLE A-2

SUMMARY OF BOTTOM FAUNA COLLECTED AT LITTLE POWDER RIVER SITE NO. 1

Class Order Family Genus	April 1976				June 1976				September 1976				January 1977			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Insecta																
Diptera																
Chironomidae																
<u>Pentaneura</u> sp. (larvae)	18	14.8	1.9	6.6	0				20	7.1	1.4	1.6	47	4.0	4.5	1.2
<u>Chironomus</u> sp. (larvae)	8	6.6	1.3	4.5	0				63	22.3	13.8	15.5	348	29.9	258.0	68.5
Other larvae	0				1	7.1	0.1	1.9	88	31.2	7.8	8.8	663	57.1	24.6	6.5
Other pupae	0				2	14.3	0.2	3.8	0				0			
-- (unidentifiable piece)	1	0.8	0.1	0.3	0				0				0			
-- (unidentifiable pupae)	1	0.8	0.6	2.1	1	7.1	0.1	1.9	2	0.7	0.2	0.2	0			
Ceratopogonidae																
<u>Palpomyia</u> sp. (larvae)	1	0.8	0.1	0.3	0				2	0.7	0.3	0.3	8	0.7	0.4	0.1
Coleoptera																
Elmidae																
<u>Dubiraphia</u> sp. (larvae)	34	27.9	2.0	6.9	4	28.6	0.4	7.5	21	7.4	1.6	1.8	45	3.9	3.7	1.0
(adults)	2	1.6	0.3	1.0	0				3	1.1	4.5	5.1	0			
-- (unidentifiable larvae)	1	0.8	0.1	0.3	0				0				0			
Trichoptera																
Psychomyiidae																
<u>Polycentropus</u> sp.	1	0.8	0.2	0.7	0				0				0			

TABLE A-2 (Cont.)

Class Order Family Genus	April 1976				June 1976				September 1976				January 1977			
	No.	% Total	Bio- mass	% Total	No.	% Total	Bio- mass	% Total	No.	% Total	Bio- mass	% Total	No.	% Total	Bio- mass	% Total
		No.	(mg)	Biomass		No.	(mg)	Biomass		No.	(mg)	Biomass		No.	(mg)	Biomass
Ephemeroptera																
Caenidae																
<u>Caenis</u> sp.	11	9.0	1.3	4.5	3	21.4	0.6	11.3	21	7.4	3.1	3.5	9	0.8	0.4	0.1
Odonata																
Coenagrionidae																
--	0				0				1	0.4	0.1	0.1	0			
--	3	2.5	1.0	3.4	0				0				0			
(unidentifiable pieces)																
Hemiptera																
Corixidae																
--	1	0.8	0.7	2.4	0				1	0.4	0.1	0.1	34	2.9	10.9	2.9
Belostomatidae																
--	0				0				0				1	0.1	71.0	18.9
--																
--	0				0				1	0.4	0.1	0.1	0			
Megaloptera																
Sialidae																
<u>Sialis fuliginosa</u>	0				0				1	0.4	2.4	2.7	0			
Crustacea																
Amphipoda																
Talitridae																
<u>Hyalolella azteca</u>	10	8.2	2.5	8.6	1	7.1	0.1	1.9	0				0			
Arachnoidea																
Hydracarina																
Unionicolidae																
<u>Neumania</u> sp.	0				0				1	0.4	0.1	0.1	0			
Clittellata																
Oligocheata																
Tubificidae																
--	28	23.0	16.5	56.9	1	7.1	0.1	1.9	39	13.8	19.7	22.2	5	0.4	0.5	0.1

TABLE A-2 (Cont.)

Class Order Family Genus	April 1976				June 1976				September 1976				January 1977			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Gastropoda																
Pulmonata																
Physidae																
<u>Physa</u> sp.	0				0				7	2.5	21.1	23.7	2	0.2	2.5	0.7
Lymnaeidae																
<u>Lymnaea</u> sp.	2	1.6	0.4	1.4	1	7.1	3.7	69.8	6	2.1	7.8	8.8	0			
Planorbidae																
<u>Gyraulus</u> sp.	0				0				1	0.4	0.8	0.9	0			
Pelecypoda																
--	0				0				4	1.4	4.0	4.5	0			
TOTALS	122	(100.0)	29.0	(100.0)	14	(100.0)	5.3	(100.0)	282	(100.0)	88.9	(100.0)	1162	(100.0)	376.5	(100.0)

TABLE A-3

SUMMARY OF BOTTOM FAUNA COLLECTED AT LITTLE POWDER RIVER SITE NO. 2

Class Order Family Genus	April 1976				June 1976				September 1976				January 1977			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Insecta																
Diptera																
Chironomidae																
Chironomus sp. (larvae)	22	11.1	0.9	1.6	4	0.8	1.4	0.9	55	7.9	11.5	3.9	132	24.0	28.1	48.8
Other pupae	0				11	2.3	1.6	1.1	0				0			
Other larvae	31	15.6	2.0	3.5	76	15.8	4.0	2.8	62	8.9	3.5	1.2	212	38.5	6.2	10.8
Pentaneura sp. (larvae)	3	1.5	0.4	0.7	17	3.5	1.6	1.1	22	3.1	1.5	0.5	14	2.5	1.3	2.3
Ceratopogonidae																
Palpomyia sp. (larvae)	8	4.0	0.6	1.0	4	0.8	0.6	0.4	6	0.9	0.4	0.1	19	3.5	1.7	3.0
--																
-- (unidentifiable pupae)	3	1.5	0.8	1.4	1	0.2	0.4	0.3	1	0.1	0.1	<0.1	0			
Tabanidae																
Chrysops sp. (larvae)	1	0.5	1.2	2.1	2	0.4	0.3	0.2	1	0.1	5.3	1.8	0			
Coleoptera																
Elmidae																
Dubiraphia sp. (larvae)	28	14.1	2.2	3.8	129	26.8	7.1	4.7	173	24.7	22.0	7.4	126	22.9	12.9	22.4
(adult)	1	0.5	0.2	0.4	11	2.3	2.2	1.5	3	0.4	0.4	0.1	0			
--																
-- (adult pieces)	0				0				3	0.4	5.7	1.9	0			
Haliplidae																
Haliplus sp.	0				2	0.4	1.3	0.9	0				0			
Ephemeroptera																
Caenidae																
Caenis sp.	30	15.1	2.2	3.8	94	19.5	15.3	10.2	124	17.7	7.2	2.4	29	5.3	2.2	3.8
Hemiptera																
Corixidae																
--	4	2.0	0.5	0.9	4	0.8	1.9	1.3	3	0.4	0.7	0.2	1	0.2	0.1	0.2

TABLE A-3 (Cont.)

Class	April 1976				June 1976				September 1976				January 1977			
	Order		Bio- mass (mg)	% Total Biomass	Order		Bio- mass (mg)	% Total Biomass	Order		Bio- mass (mg)	% Total Biomass	Order		Bio- mass (mg)	% Total Biomass
	Family	Genus			Family	Genus			Family	Genus			Family	Genus		
		No.	% Total No.			No.	% Total No.			No.	% Total No.			No.	% Total No.	
	Dipsocoridae															
	--	0				0				1	0.1	0.1	<0.1	0		
	Trichoptera															
	Phryganeidae															
	<u>Ptilostomis</u> sp.	0				0				1	0.1	0.9	0.3	0		
	--															
	(pieces of larvae)	2	1.0	0.6	1.0	0				1	0.1	0.2	<0.1	0		
	Odonata															
	Coenagrionidae															
	<u>Ischnura</u> sp.	0				0				12	1.7	2.6	0.9	2	0.4	0.6
	(pieces of nymphs)	3	1.5	0.4	0.7	1	0.2	4.5	3.0	5	0.7	2.1	0.7	0		1.0
	Gomphidae															
	--	1	0.5	0.3	0.5	0				0				0		
	<u>Progomphus</u> sp.	0				2	0.4	9.3	6.2	2	0.3	0.5	0.2	0		
	Libellulidae															
	<u>Macromia</u> sp.	0				0				1	0.1	107.6	36.2	0		
	Arachnoidea															
	Hydracarina															
	Limnocharidae															
	<u>Limnocharis</u> sp.	0				1	0.2	0.8	0.5	0				0		
	Unionicolidae															
	<u>Neumania</u> sp.	0				1	0.2	0.1	<0.1	0				0		
	Crustacea															
	Amphipoda															
	Talitridae															
	<u>Hyalalella</u> <u>azteca</u>	0				5	1.0	1.7	1.1	0				0		
	Clittellata															
	Oligocheata															
	Tubificidae															
	--	52	26.1	10.9	18.8	104	21.6	30.7	20.5	201	28.7	44.5	15.0	14	2.5	2.0
																3.5

TABLE A-3 (Cont.)

Class Order Family Genus	April 1976				June 1976				September 1976				January 1977			
			Bio-	% Total Biomass			Bio-	% Total Biomass			Bio-	% Total Biomass			Bio-	% Total Biomass
	% Total		mass		% Total		mass		% Total		mass		% Total		mass	
	No.	No.	(mg)		No.	No.	(mg)		No.	No.	(mg)		No.	No.	(mg)	
Gastropoda																
Pulmonata																
Physidae																
Physa sp.	9	4.5	29.7	51.3	9	1.9	23.2	15.5	16	2.3	46.7	15.7	1	0.2	2.5	4.3
Lymnaeidae																
Lymnaea sp.	0				1	0.2	0.2	0.1	3	0.4	2.8	0.9	0			
Planorbidae																
Gyraulus sp.	0				0				2	0.3	5.8	2.0	0			
Pelocypoda																
Sphaeriacea																
Sphaeriidae																
Sphaerium sp.	0				2	0.4	30.5	20.4	0				0			
--	1	0.5	5.0	8.6	1	0.2	11.0	7.3	0				0			
--																
--	0				0				2	0.3	25.1	8.4	0			
(halves of shells)																
TOTALS	199	(100.0)	57.9	(100.0)	482	(100.0)	149.7	(100.0)	700	(100.0)	297.2	(100.0)	550	(100.0)	57.6	(100.0)

Appendix B

BOTTOM FAUNA OF ANTELOPE CREEK

TABLE B-1

TAXONOMIC CLASSIFICATION OF BENTHIC FAUNA FROM ANTELOPE CREEK

<u>Phylum</u>	<u>Class</u>	<u>Order</u>	<u>Family</u>	<u>Genus</u>
Arthropoda	Insecta	Diptera (two-winged flies)	Chironomidae	<u>Chironomus</u> sp. <u>Pentaneura</u> sp. --*
			Ceratopogonidae	<u>Palpomyia</u> sp. <u>Probezzia</u> sp. <u>Dasyhela</u> sp.
			Tabanidae	<u>Chrysops</u> sp. <u>Tabanus</u> sp. --
			--	--
			Coleoptera (beetles)	<u>Halipilus</u> sp. <u>Berosus</u> sp.
		Ephemeroptera (mayfly)	Hydrophilidae	<u>Hydroporus</u> sp.
			Dytiscidae	<u>Caenis</u> sp.
		Odonata (damselfly and dragonflies)	Caenidae	<u>Ischnura</u> sp.
			Coenagrionidae	<u>Anomalagrion</u> sp. --
		Trichoptera (caddisfly)	Libellulidae	<u>Cordulia</u> sp.
			Psychomyiidae	<u>Polycentropus</u> sp.
		Hemiptera (water bugs)	Phryganeidae	<u>Phryganea</u> sp.
			Corixidae	--
		Crustacea	Dipsocoridae	--
			Amphipoda (shrimp)	<u>Talitridae</u> <u>Hyallela azteca</u>
Annelida	Clittellata	Arachnoidea	Unionicolidae	<u>Neumania</u> sp.
			Hygrobatidae	<u>Megapus</u> sp.
			Lebertidae	<u>Lebertia</u> sp.
		Hydracarina (water mites)	Limnesiidae	<u>Limnesia</u> sp. --
			--	--
		Oligocheata (worms)	Tubificidae	--
			Glossiphoniidae	--
		Hirudinea (leeches)	--	--
			--	--
		--	--	--
Mollusca	Gastropoda	Pulmonata (snails)	Physidae	<u>Physa</u> sp.
			Planorbidae	<u>Gyraulus</u> sp.
			Lymnaeidae	<u>Lymnaea</u> sp.
	Pelecypoda	Sphaeriacea (clams)	--	--
			Sphaeriidae	<u>Pisidium</u> sp.

*--indicates organism was unidentifiable at given taxonomic level.

TABLE B-2

SUMMARY OF BOTTOM FAUNA COLLECTED AT ANTELOPE CREEK SITE NO. 1

Class Order Family Genus	April 1976				June 1976				September 1976			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Insecta												
Diptera												
Chironomidae												
<u>Pentaneura</u> sp.	36	2.8	2.3	<0.1	10	0.8	0.8	<0.1	322	6.2	2.4	<0.1
(larvae)												
Other larvae	83	6.6	11.5	0.3	160	12.9	30.3	1.5	403	7.8	5.7	<0.1
Other pupae	0				4	0.3	0.7	<0.1	0			
Ceratopogonidae												
<u>Palpomyia</u> sp.	1	<0.1	0.2	<0.1	1	<0.1	0.1	<0.1	17	0.3	0.7	<0.1
(larvae)												
<u>Probezzia</u> sp.	0				0				1	<0.1	0.1	<0.1
(larvae)												
<u>Dasyhela</u> sp.	0				0				1	<0.1	0.1	<0.1
(larvae)												
Tabanidae												
<u>Chrysops</u> sp.	0				2	0.2	4.0	0.2	1	<0.1	0.3	<0.1
<u>Tabanus</u> sp.	0				0				1	<0.1	0.8	<0.1
--												
--	0				0				7	0.1	0.2	<0.1
(pupae)												
Coleoptera												
Haliplidae												
<u>Haliplus</u> sp.	9	0.8	7.1	0.2	4	0.3	2.4	0.1	48	0.9	38.9	0.6
(larvae)												
(adults)	0				0				7	0.1	10.7	0.2
Hydrophilidae												
<u>Berosus</u> sp.	2	0.2	1.5	<0.1	0				23	0.4	2.5	<0.1
(larvae)												
Dytiscidae												
<u>Hydroporus</u>	0				0				1	<0.1	1.5	<0.1
(adult)												
Ephemeroptera												
Caenidae												
<u>Caenis</u> sp.	18	1.4	2.2	<0.1	13	1.0	2.8	0.1	647	12.5	6.8	0.1
Trichoptera												
Psychomyiidae												
<u>Polycentropus</u> sp.	13	1.0	5.6	0.2	0				9	0.2	1.9	<0.1
Phryganeidae												
<u>Phryganea</u> sp.	0				0				2	<0.1	2.5	<0.1
--												
--	1	<0.1	0.1	<0.1	0				0			
(piece of larvae)												
Odonata												
Coenagrionidae												
<u>Ischnura</u> sp.	0				0				168	3.3	79.4	1.3
<u>Anomalagrion</u> sp.	0				0				1	<0.1	1.1	<0.1
--	7	0.6	2.2	<0.1	1	<0.1	0.2	<0.1	19	0.4	0.7	<0.1
(pieces of nymphs)												
Libellulidae												
<u>Cordulia</u> sp.	0				0				1	<0.1	35.7	0.6

TABLE B-2 (Cont.)

Class Order Family Genus	April 1976				June 1976				September 1976			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Hemiptera												
Corixidae												
--	0				0				4	<0.1	7.1	0.1
Crustacea												
Amphipoda												
Talitridae												
<u>Hyalolella azteca</u>	39	3.1	4.5	0.1	25	2.0	1.7	<0.1	1379	26.6	80.7	1.3
Arachnoidea												
Hydracarina												
Unionicolidae												
<u>Neumania</u> sp.	0				0				4	<0.1	0.6	<0.1
Hygrobatidae												
<u>Megapus</u> sp.	0				0				1	<0.1	0.1	<0.1
Lebertiidae												
<u>Lebertia</u> sp.	0				0				1	<0.1	0.1	<0.1
Limnesiidae												
<u>Limnesia</u> sp.	0				0				3	<0.1	0.1	<0.1
--	0				0				2	<0.1	0.1	<0.1
--												
(unidentified)												
Clitellata												
Oligochaeta												
Tubificidae												
--	17	1.3	3.5	0.1	28	2.3	8.0	0.4	39	0.8	2.6	<0.1
Hirudinea												
Glossiphoniidae												
--	0				1	<0.1	5.1	0.3	8	0.2	58.9	0.9
Gastropoda												
Pulmonata												
Physidae												
<u>Physa</u> sp.	205	16.2	1240.0	33.9	141	11.4	493.6	24.4	939	18.1	2534.5	41.5
Planorbidae												
<u>Gyraulus</u> sp.	4	0.3	14.8	0.4	11	0.9	10.9	0.5	134	2.6	181.6	3.0
Lymnaeidae												
<u>Lymnaea</u> sp.	526	41.5	1063.3	29.1	496	39.9	729.7	36.1	321	6.2	778.7	12.7
--												
--	0				1	<0.1	3.9	0.2	0			
--												
(appears fossilized)												
Pelecypoda												
Sphaeriacea												
Sphaeriidae												
<u>Pisidium</u> sp.	307	24.2	1301.6	35.6	344	27.7	725.9	35.9	673	13.0	2277.2	37.2
TOTALS	1268	(100.0)	3660.4	(100.0)	1242	(100.0)	2020.1	(100.0)	5189	(100.0)	6114.3	(100.0)

TABLE B-3

SUMMARY OF BOTTOM FAUNA COLLECTED AT ANTELOPE CREEK SITE NO. 2

Class Order Family Genus	April 1976				June 1976				September 1976			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Insecta												
Diptera												
Chironomidae												
<u>Pentaneura</u> sp.	1	2.6	0.1	0.4	0				13	7.9	0.3	1.8
(larvae)												
<u>Chironomus</u> sp.	0				0				7	4.3	1.6	9.4
(larvae)												
(pupae)	0				0				1	0.6	0.2	1.2
Other larvae	22	56.4	1.6	5.7	4	30.8	0.5	20.8	89	54.3	0.7	4.1
Other pupae	5	12.9	0.3	1.2	0				2	1.2	0.1	0.6
Ceratopogonidae												
<u>Palpomyia</u> sp.	5	12.8	1.6	5.7	1	7.7	0.1	4.2	10	6.1	1.0	5.8
(larvae)												
Ephemeroptera												
Caenidae												
<u>Caenis</u> sp.	0				1	7.7	0.1	4.2	37	22.6	1.6	9.4
Odonata												
Coenagrionidae												
--	0				1	7.7	0.4	16.7	1	0.6	0.1	0.6
(nymphs)												
Hemiptera												
Dipsocoridae												
--	0				0				1	0.6	0.1	0.6
Crustacea												
Amphipoda												
Talitridae												
<u>Hyalolella azteca</u>	0				1	7.7	0.1	4.2	0			
Clittellata												
Oligocheata												
Tubificidae												
--	5	12.8	1.2	4.2	1	7.7	0.1	4.2	1	0.6	0.1	0.6
Gastropoda												
Pulmonata												
Physidae												
<u>Physa</u> sp.	1	2.6	23.5	83.0	1	7.7	0.6	25.0	2	1.2	11.3	66.1
Lymnaeidae												
<u>Lymnaea</u> sp.	0				1	7.7	0.1	4.2	0			
Pelecypoda												
Sphaeriacea												
Sphaeriidae												
<u>Pisidium</u> sp.	0				2	15.4	0.4	16.7	0			
TOTALS	39	(100.0)	28.3	(100.0)	13	(100.0)	2.4	(100.0)	164	(100.0)	17.1	(100.0)

Appendix C

BOTTOM FAUNA OF SCHOOL AND LITTLE THUNDER CREEKS

TABLE C-1

TAXONOMIC CLASSIFICATION OF THE BENTHIC FAUNA OF SCHOOL CREEK

<u>Phylum</u>	<u>Class</u>	<u>Order</u>	<u>Family</u>	<u>Genus</u>
Arthropoda	Insecta	Diptera (two-winged flies)	Chironomidae	<u>Chironomus</u> sp. <u>Pentaneura</u> sp. -- *
			Ceratopogonidae	<u>Palpomyia</u> sp. <u>Dasyhelea</u> sp.
			Tabanidae	<u>Chrysops</u> sp.
			Stratiomyidae	<u>Nemotelus</u> sp.
			Dolichopodidae	--
			--	--
		Coleoptera (beetles)	Elmidae	<u>Dubiraphia</u> sp.
			Haliplidae	<u>Haliplus</u> sp.
			Dytiscidae	<u>Hydroporus/Hygrotus</u> sp. <u>Celina</u> sp. <u>Coptotomus</u> sp.
			Hydrophilidae	<u>Berosus</u> sp. --
			--	--
		Ephemeroptera (mayfly)	Caenidae	<u>Caenis</u> sp.
		Trichoptera (caddisfly)	Limnephilidae	<u>Limnephilis</u> sp. --
		Hemiptera (water bugs)	Dipsocoridae	--
		Odonata	Lestidae	<u>Lestes</u> sp.
			Coenagrionidae	<u>Ischnura</u> sp. --
	Crustacea	Amphipoda	Talitridae	<u>Hyallela azteca</u>
Annelida	Clittellata	Oligocheata	Tubificidae	--
Mollusca	Gastropoda	Pulmonata	Physidae	<u>Physa</u> sp.
			Planorbidae	<u>Gyraulus</u> sp.
			Lymnaeidae	<u>Lymnaea</u> sp.
	Pelecypoda	Sphaeriacea	Sphaeriidae	<u>Pisidium</u> sp.

*--indicates organism was unidentifiable at given taxonomic level.

TABLE C-2

TAXONOMIC CLASSIFICATION OF BENTHIC FAUNA FROM LITTLE THUNDER CREEK

<u>Phylum</u>	<u>Class</u>	<u>Order</u>	<u>Family</u>	<u>Genus</u>
Arthropoda	Insecta	Diptera (two-winged flies)	Chironomidae	<u>Chironomus</u> sp. <u>Pentaneura</u> sp. ---*
			Ceratopogonidae	<u>Dasyhelea</u> sp. <u>Palpomyia</u> sp. <u>Chrysops</u> sp. <u>Dixa</u> sp. <u>Dubiraphia</u> sp. <u>Haliplus</u> sp. <u>Berosus</u> sp. <u>Donacia</u> sp. <u>Hydroporus/Hygrotus</u> <u>Hydroporus</u> sp. ---
			Tabanidae	
			Dixidae	
			Elmidae	
		Coleoptera (beetles)	Haliplidae	
			Hydrophilidae	
			Chrysomelidae	
			Dytiscidae	

		Ephemeroptera (mayfly)	Caenidae	<u>Caenis</u> sp. ---
		Hemiptera (water bugs)	Dipsocoridae	---
		Odonata (damselfly and dragonflies)	Coenagrionidae	<u>Ischnura</u> sp. ---
		Trichoptera (caddisfly)	Gomphidae	<u>Gomphus</u> sp.
			Phryganeidae	<u>Phryganea</u> sp.
			Limnephilidae	<u>Limnephilus</u> sp.
			Psychomyiidae	<u>Polycentropus</u> sp.
			Talitridae	<u>Hyallela azteca</u>
Annelida	Crustacea	Amphipoda (shrimp)		
	Arachnoidea	Hydracarina (water mites)	Limnocharidae Pionidae	<u>Limnocharis</u> sp. <u>Forelia</u> sp.
	Clittellata	Oligocheata (worms)	Tubificidae	---
		Hirudinea (leeches)	Glossiphoniidae	<u>Glossiphonia</u> sp. <u>Helobdella stagnalis</u>
	Gastropoda	Pulmonata (snails)	Physidae	<u>Physa</u> sp.
			Lymnaeidae	<u>Lymnaea</u> sp.
			Ancylidae	<u>Ferrissia</u> sp.
			Planorbidae	<u>Gyraulus</u> sp. ---
	Pelecypoda	Sphaeriacea (clams)	---	
			Sphaeriidae	<u>Pisidium</u> sp.

*---indicates organism was unidentifiable at given taxonomic level.

TABLE C-3

SUMMARY OF BOTTOM FAUNA COLLECTED AT SCHOOL CREEK

Class Order Family Genus	May 1976				June 1976				September 1976				January 1977			
	% Total		Bio- mass (mg)	% Total Biomass	% Total		Bio- mass (mg)	% Total Biomass	% Total		Bio- mass (mg)	% Total Biomass	% Total		Bio- mass (mg)	% Total Biomass
	No.	No.			No.	No.			No.	No.			No.	No.		
Insecta																
Diptera																
Chironomidae																
Chironomus sp. (larvae)	0				0				217	12.5	40.4	0.6	107	40.2	109.3	3.5
Pentaneura sp. (larvae)	0				0				17	1.0	0.4	<0.1	7	2.6	0.4	<0.1
Other larvae	0				1	<0.1	0.1	<0.1	10	0.6	0.6	<0.1	1	0.4	0.1	<0.1
Other pupae	0				0				3	0.2	1.1	<0.1	0			
Ceratopogonidae																
Palpomyia sp. (larvae)	0				1	<0.1	0.1	<0.1	4	0.2	0.1	<0.1	0			
Dasyhelea sp. (larvae)	0				0				1	0.1	0.1	<0.1	0			
Tabanidae																
Chrysops sp. (larvae)	3	0.2	7.0	<0.1	10	0.6	19.1	0.2	5	0.3	22.2	0.4	0			
Stratiomyidae																
Nemotelus sp. (larvae)	2	0.1	1.1	<0.1	0				0				0			
Dolichopodidae																
-- (larvae)	0				1	<0.1	0.4	<0.1	0				0			
-- (piece of larvae)	0				1	<0.1	0.1	<0.1	0				0			
Coleoptera																
Elmidae																
Dubiraphia sp. (larvae)	0				0				71	4.1	5.5	<0.1	1	0.4	0.6	<0.1
(adults)	1	0.1	0.2	<0.1	0				0				0			

TABLE C-3 (Cont.)

Class Order Family Genus	May 1976				June 1976				September 1976				January 1977			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Haliplidae																
Haliphus sp.	1	0.1	0.2	<0.1	0				4	0.2	3.2	<0.1	0			
(larvae)																
(adults)	0				1	<0.1	0.7	<0.1	0				0			
Dytiscidae																
Hydroporus/Hygrotus	2	0.1	0.3	<0.1	0				0				0			
(larvae)																
Celina sp.	0				0				3	0.2	4.2	<0.1	0			
(adults)																
Coptotomus sp.	0				0				1	0.1	9.2	0.1	0			
(adults)																
Hydrophilidae																
Berosus sp.	0				6	0.4	1.0	<0.1	1	0.1	0.2	<0.1	0			
(larvae)																
--	1	0.1	0.2	<0.1	0				0				0			
(pieces of larvae)																
--	2	0.1	3.1	<0.1	1	<0.1	1.4	<0.1	3	0.2	4.9	<0.1	0			
(pieces of adults)																
Ephemeroptera																
Caenidae																
Caenis sp.	1	0.1	0.1	<0.1	0				24	1.4	0.9	<0.1	0			
Trichoptera																
Limnephilidae																
Limnephilis sp.	20	1.1	117.2	0.6	0				0				0			
--	2	0.1	11.7	<0.1	0				0				0			
(pieces of larvae)																
Hemiptera																
Dipsocoridae	1	0.1	0.1	<0.1	0				0				0			
--																
Odonata																
Lestidae																
Lestes sp.	0				2	0.1	3.5	<0.1	0				0			

TABLE C-3 (Cont.)

Class Order Family Genus	May 1976				June 1976				September 1976				January 1977			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Coenagrionidae																
<u>Ischnura</u> sp.	0				0				5	0.3	0.1	<0.1	0			
--	0				0				1	0.1	0.1	<0.1	0			
Crustacea																
Amphipoda																
Talitridae																
<u>Hyalolella azteca</u>	2	0.1	0.6	<0.1	0				89	5.1	28.7	0.5	0			
Clittellata																
Oligochaeta																
Tubificidae																
--	85	4.9	22.8	0.1	158	9.4	38.8	0.4	39	2.2	9.3	0.2	1	0.4	0.1	<0.1
Gastropoda																
Pulmonata																
Physidae																
<u>Physa</u> sp.	1192	68.1	17508.6	96.9	729	43.5	8226.7	91.1	654	37.7	5231.8	81.3	105	39.5	2971.3	93.9
Planorbidae																
<u>Gyraulus</u> sp.	428	24.4	386.0	2.1	728	43.5	678.2	7.5	577	33.2	1056.2	16.4	43	16.2	79.4	2.5
Lymnaeidae																
<u>Lymnaea</u> sp.	7	0.4	14.0	<0.1	36	2.1	63.5	0.7	2	0.1	4.5	<0.1	1	0.4	2.4	<0.1
Pelecypoda																
Sphaeriacea																
Sphaeriidae																
<u>Pisidium</u> sp.	1	0.1	1.3	<0.1	0				5	0.3	7.6	0.1	0			
TOTALS	1751	(100.0)	18074.5	(100.0)	1675	(100.0)	9033.6	(100.0)	1736	(100.0)	6431.3	(100.0)	266	(100.0)	3163.6	(100.0)

TABLE C-4

SUMMARY OF BOTTOM FAUNA COLLECTED AT LITTLE THUNDER CREEK

Class Order Family Genus	May 1976				June 1976				September 1976				January 1977			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Insecta																
Diptera																
Chironomidae																
Chironomus sp. (larvae)	0				0				0				2	<0.1	1.3	<0.1
Pentaneura sp. (larvae)	52	0.8	2.3	<0.1	5	<0.1	0.6	<0.1	0				32	0.4	2.3	<0.1
Other larvae	1176	17.4	293.0	4.9	11	0.2	1.4	<0.1	20	0.4	1.9	<0.1	808	11.1	29.5	0.5
Other pupae	14	0.2	0.5	<0.1	0				0				0			
Ceratopogonidae																
Dasyhelea sp. (larvae)	18	0.3	0.5	<0.1	0				2	<0.1	0.1	<0.1	0			
Palpomyia sp. (larvae)	1	<0.1	0.1	<0.1	1	<0.1	0.1	<0.1	0				1	<0.1	0.1	<0.1
Tabanidae																
Chrysops sp. (larvae)	6	0.1	23.2	0.4	17	0.3	76.0	1.0	1	<0.1	0.8	<0.1	4	<0.1	12.8	0.2
Dixidae																
Dixa sp. (larvae)	0				0				1	<0.1	1.3	<0.1	0			
Coleoptera																
Elmidae																
Dubiraphia sp. (larvae)	34	0.5	2.6	<0.1	194	3.0	7.6	0.1	268	4.3	12.7	0.2	60	0.8	4.5	<0.1
(adults)	1	<0.1	0.4	<0.1	5	<0.1	1.5	<0.1	4	<0.1	1.2	<0.1	3	<0.1	0.6	<0.1
Haliplidae																
Haliphus sp. (larvae)	38	0.6	1.6	<0.1	10	0.2	2.3	<0.1	10	0.2	1.0	<0.1	9	0.1	5.0	<0.1
(adults)	1	<0.1	0.4	<0.1	1	<0.1	0.6	<0.1	0				0			
Hydrophilidae																
Berosus sp. (larvae)	3	<0.1	0.7	<0.1	6	0.1	1.1	<0.1	9	0.1	1.1	<0.1	0			

TABLE C-4 (Cont.)

Class	May 1976				June 1976				September 1976				January 1977				
	Order	% Total	Bio- mass	% Total	No.	% Total	Bio- mass	% Total	No.	% Total	Bio- mass	% Total	No.	% Total	Bio- mass	% Total	
	Family Genus																No.
	Chrysomelidae																
	Donacia sp.	0			1	<0.1	0.1	<0.1	0				0				
	(larvae)																
	Dytiscidae																
	Hydroporus/Hygrotus	0			1	<0.1	0.1	<0.1	0				0				
	(larvae)																
	Hydroporus	0			0				0				1	<0.1	0.1	<0.1	
	(larvae)																
	--	2	<0.1	2.3	<0.1	0			1	<0.1	17.2	0.3	0				
	(pieces of adults)																
	Ephemeroptera																
	Caenidae																
	Caenis sp.	283	4.2	20.9	0.3	75	1.1	22.4	0.30	511	8.3	55.6	1.0	346	4.7	37.5	0.6
	Hemiptera																
	Dipsocoridae																
	--	0			0				1	<0.1	0.2	<0.1	0				
	Odonata																
	Coenagrionidae																
	Ischnura sp.	45	0.7	6.9	0.1	5	<0.1	3.1	<0.1	38	0.6	4.5	<0.1	75	1.0	41.1	0.6
	--	0			3	<0.1	0.6	<0.1	0				0				
	(pieces of nymphs)																
	Gomphidae																
	Gomphus sp.	1	<0.1	8.4	0.1	1	<0.1	21.3	0.3	1	<0.1	0.2	<0.1	0			
	Trichoptera																
	Phryganeidae																
	Phryganea sp.	0			0				0				3	<0.1	115.8	1.9	
	Limnephilidae																
	Limnephilus sp.	0			0				0				6	<0.1	15.5	0.3	
	Psychomyiidae																
	Polycentropus sp.	0			0				0				12	0.2	2.2	<0.1	
	Crustacea																
	Amphipoda																
	Talitridae																
	Hyallela azteca	196	2.9	17.7	0.3	116	1.8	7.4	0.1	207	3.4	16.1	0.3	804	11.0	86.5	1.4

TABLE C-4 (Cont.)

Class Order Family Genus	May 1976				June 1976				September 1976				January 1977			
	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass	No.	% Total No.	Bio- mass (mg)	% Total Biomass
Arachnoidea																
Hydracarina																
Limnocharidae																
Limnocharis sp.	5	<0.1	3.0	<0.1	2	<0.1	0.3	<0.1	2	<0.1	0.2	<0.1	0			
Pionidae																
Forelia sp.	0				0				0				1	<0.1	0.1	<0.1
Clittellata																
Oligocheata																
Tubificidae																
--	23	0.3	2.3	<0.1	18	0.3	2.6	<0.1	1	<0.1	0.4	<0.1	8	0.1	0.7	<0.1
Hirudinea																
Glossiphoniidae																
Glossiphonia sp.	0				0				1	<0.1	7.9	0.1	0			
Helobdella stagnalis	0				0				0				1	<0.1	1.5	<0.1
Gastropoda																
Pulmonata																
Physidae																
Physa sp.	1136	16.8	3200.7	53.2	1732	26.4	4601.6	57.3	790	12.8	2533.8	42.2	780	10.7	2462.1	41.1
Lymnaeidae																
Lymnaea sp.	49	0.7	74.7	1.2	211	3.2	299.4	3.7	60	1.0	70.1	1.2	33	0.5	44.6	0.7
Ancylidae																
Ferrissia sp.	370	5.5	189.4	3.1	474	7.2	298.3	3.7	465	7.5	257.5	4.3	474	6.5	233.8	3.9
Planorbidae																
Gyraulus sp.	3287	48.7	2154.9	35.8	3667	55.8	2658.8	33.1	3756	60.9	2985.2	49.7	3831	52.5	2888.7	48.2
--																
--	0				1	<0.1	0.4	<0.1	0				0			
Pelecypoda																
Sphaeriacea																
Sphaeriidae																
Pisidium sp.	12	0.2	10.1	0.2	12	0.2	20.1	0.30	16	0.3	35.6	0.6	8	0.1	9.0	0.2
TOTALS	6753.0	(100.0)	6016.6	(100.0)	6569.0	(100.0)	8027.7	(100.0)	6165.0	(100.0)	6004.0	(100.0)	7302.0	(100.0)	5995.3	(100.0)

Appendix D

WRI WATER QUALITY DATA SHEETS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected April 28, 1976 Facility Name _____

Stream Name(s) Little Powder River

Source of Sample: (Exact Location)
Site #1

Physical Observations, Remarks:

Weather Cond. Cool & Cloudy

Temp. (air) 43 °F
 Ground Cond. _____

Flow <u>5.8 cfs</u>	Field Dissolved Oxygen <u>10.8 mg/l</u>	Field pH <u>8.2</u>	Field Temp. <u>42</u> °F.
------------------------	--	------------------------	------------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>10.43</u>	<u>210</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>9.21</u>	<u>110</u>	_____	Bicarbonate (HCO ₃)	<u>7.73</u>	<u>470</u>	_____
Sodium (Na)	<u>15.03</u>	<u>350</u>	_____	Sulfate (SO ₄)	<u>26.39</u>	<u>1300</u>	_____
Potassium (K)	<u>0.47</u>	<u>19</u>	_____	Chloride (Cl)	<u>0.41</u>	<u>14</u>	_____
_____	_____	_____	_____	Nitrate (NO ₃)	<u>0.01</u>	<u>0.4</u>	_____
_____	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	<u>0.05</u>	_____
_____	_____	_____	_____	Fluoride (F)	<u>0.05</u>	<u>1.0</u>	_____
Total Cations	<u>35.14</u>	_____	_____	Total Anions	<u>34.59</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>2840</u> (____) Conductance (µMHOS)	_____	<u>0.3</u> (____) Ammonia (N)	_____
<u>27</u> (____) COD	_____	<u>1.8</u> (____) Total Kjeldahl (N)	_____
<u>8.3</u> (____) pH	_____	<u>0.05</u> (____) Phosphate (PO ₄)	_____
<u>40</u> (____) Turbidity (NTU)	_____	<u>84</u> (____) Susp. Solids	_____
<u>980</u> (____) Hardness	_____	<u>16</u> (____) Vol. Susp. Solids	_____
_____ (____) Alkalinity	_____	<u>2410</u> (____) TDS	_____
_____ (____) Total Acidity	_____		
_____ (____) Free Acidity	_____		
<u>7.0</u> (____) Silica (SiO ₂)	_____		
<u><0.1</u> (____) Nitrite	_____		
<u>43</u> Sodium %	_____		
<u>230</u> Total CO ₃	_____		

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____
 Date sample rec'd: _____ Time: _____
 Date analysis completed: _____
 Date results forwarded: _____
 Total tests requested: _____ Tests run: _____
 Lab Section: _____ Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: April 28, 1976Stream Name(s): Little Powder RiverSource of Sample: Site #1

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<0.05() Arsenic	<0.1 () Lead
<0.5 () Barium	0.2 () Manganese
0.45 () Boron	<0.1 () Mercury
<0.01() Cadmium	<0.01() Nickel
0.03() Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.03 () Zinc
1.0 () Fluoride	<0.02 () Cyanide
0.48 () Iron (Total)	<0.01() MBAS
() Iron (Dissolved)	0.003() Phenol (ppm)
BOD	1.7 () Oil & Grease
Fecal Coliforms 100 ml	0.0 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected April 28, 1976 Facility Name _____

Stream Name(s) _____
Little Powder River
 Source of Sample: (Exact Location) _____
Site #2

Physical Observations, Remarks: _____ Weather Cond. Cool & Cloudy
 Temp. (air) _____ 43 °F
 Ground Cond. _____
 Flow 6.5 cfs Field Dissolved Oxygen 11.5 mg/l Field pH 8.1 Field Temp. 43 °F

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>4.62</u>	<u>93</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>2.22</u>	<u>27</u>		Bicarbonate (HCO ₃)	<u>6.62</u>	<u>400</u>	
Sodium (Na)	<u>16.09</u>	<u>370</u>		Sulfate (SO ₄)	<u>18.08</u>	<u>870</u>	
Potassium (K)	<u>0.23</u>	<u>9.1</u>		Chloride (Cl)	<u>0.36</u>	<u>13</u>	
				Nitrate (NO ₃)	<u>0.01</u>	<u>0.5</u>	
				*Phosphate(PO ₄)as(P)		<u>0.05</u>	
				Fluoride (F)	<u>0.04</u>	<u>0.8</u>	
Total Cations	<u>23.16</u>			Total Anions	<u>25.11</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>2260</u> () Conductance(μMHOS)		<u>0.6</u> () Ammonia (N)	
<u>27</u> () COD		<u>1.4</u> () Total Kjeldahl (N)	
<u>8.3</u> () pH		<u>0.05</u> () Phosphate (PO ₄)	
<u>80</u> () Turbidity (NTU)		<u>104</u> () Susp. Solids	<u>1780</u>
<u>340</u> () Hardness		<u>12</u> () Vol. Susp. Solids	Total
() Alkalinity		<u>1680</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>7.5</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>69</u> Sodium %		Date results forwarded: _____	
<u>200</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: April 28, 1976Stream Name(s): Little Powder RiverSource of Sample: Site #2

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.2 () Manganese
0.15 () Boron	0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
0.03 () Copper	0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.13 () Zinc
0.8 () Fluoride	<0.02 () Cyanide
0.26 () Iron (Total)	<0.01 () MBAS
() Iron (Dissolved)	0.003 () Phenol (ppm)
BOD	1.6 () Oil & Grease
Fecal Coliforms 100 ml	0.0 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected June 23, 1976 Facility Name _____

Stream Name(s) _____

Little Powder River

Source of Sample: (Exact Location) _____

Site #1Physical Observations, Remarks: _____ Weather Cond. Cool & CloudyTemp. (air) 55 °F

Ground Cond. _____

Flow <u>9.2 cfs</u>	Field Dissolved Oxygen <u>4.7 mg/l</u>	Field pH <u>7.8</u>	Field Temp. <u>59°F</u>
------------------------	---	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>3.77</u>	<u>76</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>3.08</u>	<u>38</u>		Bicarbonate (HCO ₃)	<u>3.60</u>	<u>220</u>	
Sodium (Na)	<u>5.60</u>	<u>130</u>		Sulfate (SO ₄)	<u>8.65</u>	<u>420</u>	
Potassium (K)	<u>0.26</u>	<u>10</u>		Chloride (Cl)	<u>0.21</u>	<u>7.4</u>	
				Nitrate (NO ₃)	<u>0.02</u>	<u>1.5</u>	
				*Phosphate (PO ₄) as (P)		<u>0.14</u>	
				Fluoride (F)	<u>0.02</u>	<u>0.4</u>	
Total Cations	<u>12.71</u>			Total Anions	<u>12.50</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>1110</u> () Conductance (µMHOS)		<u>0.0</u> () Ammonia (N)	
<u>25</u> () COD		<u>1.8</u> () Total Kjeldahl (N)	
<u>7.9</u> () pH		<u>0.14</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>590</u> () Susp. Solids	<u>1460</u>
<u>340</u> () Hardness		<u>50</u> () Vol. Susp. Solids	Total
() Alkalinity		<u>872</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>13</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>44</u> Sodium %		Date results forwarded: _____	
<u>110</u> Total CO ₂		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: June 23, 1976Stream Name(s): Little Powder RiverSource of Sample: Site #1

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.07 () Manganese
0.14 () Boron	<0.001() Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001() Selenium
<0.01 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.3 () Zinc
0.4 () Fluoride	<0.02 () Cyanide
2.86 () Iron (Total)	<0.01 () MBAS
1.55 () Iron (Dissolved)	0.002() Phenol (ppm)
BOD	1.3 () Oil & Grease
Fecal Coliforms 100 ml	<0.001() Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected June 23, 1976 Facility Name _____

Stream Name(s) _____

Little Powder River

Source of Sample: (Exact Location) _____

Site #2

Physical Observations, Remarks: _____

Weather Cond. Clearing &
WarmTemp. (air) 59 °F
Ground Cond. _____

Flow <u>17.7 cfs</u>	Field Dissolved Oxygen <u>5.4 mg/l</u>	Field pH <u>7.8</u>	Field Temp. <u>66°F</u>
-------------------------	---	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>2.69</u>	<u>54</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>2.26</u>	<u>28</u>	_____	Bicarbonate (HCO ₃)	<u>3.05</u>	<u>190</u>	_____
Sodium (Na)	<u>5.26</u>	<u>120</u>	_____	Sulfate (SO ₄)	<u>6.99</u>	<u>340</u>	_____
Potassium (K)	<u>0.21</u>	<u>8.1</u>	_____	Chloride (Cl)	<u>0.21</u>	<u>7.4</u>	_____
_____	_____	_____	_____	Nitrate (NO ₃)	<u>0.02</u>	<u>1.5</u>	_____
_____	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	<u>0.14</u>	_____
_____	_____	_____	_____	Fluoride (F)	<u>0.02</u>	<u>0.3</u>	_____
Total Cations	<u>10.42</u>	_____	_____	Total Anions	<u>10.29</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>970</u> (____) Conductance (µMHOS)	_____	<u>0.0</u> (____) Ammonia (N)	_____
<u>25</u> (____) COD	_____	<u>2.1</u> (____) Total Kjeldahl (N)	_____
<u>7.8</u> (____) pH	_____	<u>0.14</u> (____) Phosphate (PO ₄)	_____
_____ (____) Turbidity (NTU)	_____	<u>560</u> (____) Susp. Solids	<u>1380</u>
<u>250</u> (____) Hardness	_____	<u>50</u> (____) Vol. Susp. Solids	Total
_____ (____) Alkalinity	_____	<u>816</u> (____) TDS	_____
_____ (____) Total Acidity	_____	FOR LAB USE ONLY	
_____ (____) Free Acidity	_____	Lab Number: _____ Rec'd by: _____	
<u>13</u> (____) Silica (SiO ₂)	_____	Date sample rec'd: _____ Time: _____	
<u><0.1</u> (____) Nitrite	_____	Date analysis completed: _____	
<u>50</u> Sodium %	_____	Date results forwarded: _____	
<u>91</u> Total CO ₂	_____	Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: June 23, 1976Stream Name(s): Little Powder RiverSource of Sample: Site #2

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<u><0.05</u> () Arsenic	<u><0.1</u> () Lead
<u><0.5</u> () Barium	<u>0.18</u> () Manganese
<u>0.12</u> () Boron	<u><0.001</u> () Mercury
<u><0.01</u> () Cadmium	<u><0.1</u> () Nickel
<u><0.01</u> () Copper	<u><0.001</u> () Selenium
<u><0.1</u> () Chromium (tri)	<u><0.5</u> () Silver
<u> </u> () Chromium (hex)	<u>0.34</u> () Zinc
<u>0.3</u> () Fluoride	<u><0.02</u> () Cyanide
<u>4.22</u> () Iron (Total)	<u><0.01</u> () MBAS
<u>0.63</u> () Iron (Dissolved)	<u>0.004</u> () Phenol (ppm)
<u> </u> BOD	<u>0.4</u> () Oil & Grease
<u> </u> Fecal Coliforms 100 ml	<u><0.001</u> () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected September 23, 1976 Facility Name _____

Stream Name(s) Little Powder River
 Source of Sample: (Exact Location) Site #1

Physical Observations, Remarks: _____ Weather Cond. Cool-Light rain

Temp. (air) 52 °F
 Ground Cond. _____

Flow <u>0.8 cfs</u>	Field Dissolved Oxygen <u>7.8</u>	Field pH <u>8.1</u>	Field Temp. <u>58°F</u>
------------------------	--------------------------------------	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>16.97</u>	<u>340</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>14.23</u>	<u>170</u>	_____	Bicarbonate (HCO ₃)	<u>4.82</u>	<u>290</u>	_____
Sodium (Na)	<u>10.77</u>	<u>250</u>	_____	Sulfate (SO ₄)	<u>40.04</u>	<u>1900</u>	_____
Potassium (K)	<u>1.07</u>	<u>42</u>	_____	Chloride (Cl)	<u>0.27</u>	<u>9.6</u>	_____
_____	_____	_____	_____	Nitrate (NO ₃)	<u>0.00</u>	<u>0.0</u>	_____
_____	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	<u>0.02</u>	_____
_____	_____	_____	_____	Fluoride (F)	<u>0.06</u>	<u>1.1</u>	_____
Total Cations	<u>43.04</u>	_____	_____	Total Anions	<u>45.19</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>3250</u> () Conductance (μMHOS)	_____	<u>0.0</u> () Ammonia (N)	_____
<u>14</u> () COD	_____	<u>1.1</u> () Total Kjeldahl (N)	_____
<u>8.0</u> () pH	_____	<u>0.02</u> () Phosphate (PO ₄)	_____
() Turbidity (NTU)	_____	<u>24</u> () Susp. Solids	_____
<u>1600</u> () Hardness	_____	<u>24</u> () Vol. Susp. Solids	_____
() Alkalinity	_____	<u>3250</u> () TDS	_____
() Total Acidity	_____		
() Free Acidity	_____		
<u>4.8</u> () Silica (SiO ₂)	_____		
<u><0.1</u> () Nitrite	_____		
<u>25</u> Sodium %	_____		
<u>140</u> Total CO ₃	_____		

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____
 Date sample rec'd: _____ Time: _____
 Date analysis completed: _____
 Date results forwarded: _____
 Total tests requested: _____ Tests run: _____
 Lab Section: _____ Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: September 23, 1976Stream Name(s): Little Powder RiverSource of Sample: Site #1

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	0.2 () Lead
<0.5 () Barium	<0.05 () Manganese
2.09 () Boron	<0.001() Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001() Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	<0.02 () Zinc
1.1 () Fluoride	<0.02 () Cyanide
0.00 () Iron (Total)	<0.01 () MBAS
0.00 () Iron (Dissolved)	<0.001() Phenol (ppm)
BOD	1.3 () Oil & Grease
Fecal Coliforms 100 ml	<0.001() Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected September 23, 1976 Facility Name _____

Stream Name(s) Little Powder River
 Source of Sample: (Exact Location) Site #2

Physical Observations, Remarks: _____ Weather Cond. Cool & Cloudy
 Temp. (air) 54 °F
 Ground Cond. _____
 Flow 0.5 cfs Field Dissolved Oxygen 7.9 Field pH 8.1 Field Temp. 59°F

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>16.17</u>	<u>320</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>14.15</u>	<u>170</u>	_____	Bicarbonate (HCO ₃)	<u>5.00</u>	<u>310</u>	_____
Sodium (Na)	<u>12.78</u>	<u>290</u>	_____	Sulfate (SO ₄)	<u>38.21</u>	<u>1800</u>	_____
Potassium (K)	<u>1.07</u>	<u>42</u>	_____	Chloride (Cl)	<u>0.26</u>	<u>9.3</u>	_____
_____	_____	_____	_____	Nitrate (NO ₃)	<u>0.00</u>	<u>0.0</u>	_____
_____	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	<u>0.02</u>	_____
_____	_____	_____	_____	Fluoride (F)	<u>0.06</u>	<u>1.2</u>	_____
Total Cations	<u>44.17</u>	_____	_____	Total Anions	<u>43.53</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>3410</u> (____) Conductance (µMHOS)	_____	<u>0.0</u> (____) Ammonia (N)	_____
<u>13</u> (____) COD	_____	<u>0.7</u> (____) Total Kjeldahl (N)	_____
<u>8.1</u> (____) pH	_____	<u>0.02</u> (____) Phosphate (PO ₄)	_____
_____ (____) Turbidity (NTU)	_____	<u>12</u> (____) Susp. Solids	_____
<u>1500</u> (____) Hardness	_____	<u>12</u> (____) Vol. Susp. Solids	_____
_____ (____) Alkalinity	_____	<u>3260</u> (____) TDS	_____
_____ (____) Total Acidity	_____	FOR LAB USE ONLY	
_____ (____) Free Acidity	_____	Lab Number: _____ Rec'd by: _____	
<u>2.4</u> (____) Silica (SiO ₂)	_____	Date sample rec'd: _____ Time: _____	
<u><0.1</u> (____) Nitrite	_____	Date analysis completed: _____	
<u>29</u> Sodium %	_____	Date results forwarded: _____	
<u>150</u> Total CO ₃	_____	Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: September 23, 1976Stream Name(s): Little Powder RiverSource of Sample: Site #2

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	0.3 () Lead
<0.5 () Barium	<0.05 () Manganese
3.97 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	<0.02 () Zinc
1.2 () Fluoride	<0.02 () Cyanide
0.00 () Iron (Total)	<0.01 () MBAS
0.00 () Iron (Dissolved)	<0.001 () Phenol (ppm)
BOD	1.2 () Oil & Grease
Fecal Coliforms 100 ml	<0.001 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected January 20, 1977 Facility Name _____

Stream Name(s) _____
Little Powder River
 Source of Sample: (Exact Location) _____
Site #1

Physical Observations, Remarks: <u>Ice is 12" thick</u>			Weather Cond. <u>Clear-Cold</u>
			Temp. (air) <u>37</u> °F
			Ground Cond. _____
Flow -	Field Dissolved Oxygen 3.2 mg/l	Field pH 7.9	Field Temp. 32°F

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>8.98</u>	<u>180</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>9.34</u>	<u>110</u>	_____	Bicarbonate (HCO ₃)	<u>11.80</u>	<u>720</u>	_____
Sodium (Na)	<u>33.32</u>	<u>770</u>	_____	Sulfate (SO ₄)	<u>35.73</u>	<u>1700</u>	_____
Potassium (K)	<u>0.33</u>	<u>13</u>	_____	Chloride (Cl)	<u>0.08</u>	<u>2.9</u>	_____
	_____	_____	_____	Nitrate (NO ₃)	<u>0.01</u>	<u>0.5</u>	_____
	_____	_____	_____	*Phosphate (PO ₄) as (P)	<u>0.02</u>	<u>0.02</u>	_____
	_____	_____	_____	Fluoride (F)	<u>0.06</u>	<u>1.2</u>	_____
Total Cations	<u>52.17</u>	_____	_____	Total Anions	<u>47.68</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>4040</u> () Conductance (µMHOS)	_____	<u>0.0</u> () Ammonia (N)	_____
<u>16</u> () COD	_____	<u>0.6</u> () Total Kjeldahl (N)	_____
<u>8.0</u> () pH	_____	<u>0.02</u> () Phosphate (PO ₄)	_____
() Turbidity (NTU)	_____	<u>40</u> () Susp. Solids	_____
<u>920</u> () Hardness	_____	<u>8</u> () Vol. Susp. Solids	_____
() Alkalinity	_____	<u>3270</u> () TDS	_____
() Total Acidity	_____		
() Free Acidity	_____		
<u>13</u> () Silica (SiO ₂)	_____		
<u><0.1</u> () Nitrite	_____		
<u>64</u> Sodium %	_____		
<u>350</u> Total CO ₂	_____		

3310
Total

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____
 Date sample rec'd: _____ Time: _____
 Date analysis completed: _____
 Date results forwarded: _____
 Total tests requested: _____ Tests run: _____
 Lab Section: _____ Supervisor: _____

Transported by: _____
 Received by: _____

Transported by: _____
 Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: January 20, 1977Stream Name(s): Little Powder RiverSource of Sample: Site #1

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<0.05 () Arsenic	0.6 () Lead
<0.5 () Barium	0.59 () Manganese
3.2 () Boron	<0.001 () Mercury
0.03 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.05 () Silver
() Chromium (hex)	<0.02 () Zinc
1.2 () Fluoride	<0.02 () Cyanide
0.44 () Iron (Total)	0.02 () MBAS
0.00 () Iron (Dissolved)	0.006 () Phenol (ppm)
BOD	1.1 () Oil & Grease
Fecal Coliforms 100 ml	0.001 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected January 20, 1977 Facility Name _____

Stream Name(s) Little Powder River
 Source of Sample: (Exact Location) Site #2

Physical Observations, Remarks: Ice was 12" thick Weather Cond. Clear-Cold
 Temp. (air) 39 °F
 Ground Cond. Deep snow
 Flow - Field Dissolved Oxygen - Field pH 7.9 Field Temp. 32°F

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>6.36</u>	<u>130</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>4.70</u>	<u>52</u>		Bicarbonate (HCO ₃)	<u>11.00</u>	<u>670</u>	
Sodium (Na)	<u>31.43</u>	<u>720</u>		Sulfate (SO ₄)	<u>32.64</u>	<u>1600</u>	
Potassium (K)	<u>0.36</u>	<u>14</u>		Chloride (Cl)	<u>0.09</u>	<u>33</u>	
				Nitrate (NO ₃)	<u>0.01</u>	<u>0.8</u>	
				*Phosphate (PO ₄) as (P)	<u>0.03</u>	<u>0.04</u>	
				Fluoride (F)	<u>0.06</u>	<u>1.1</u>	
Total Cations	<u>42.85</u>			Total Anions	<u>43.80</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>3780</u> () Conductance (μMHOS)		<u>0.0</u> () Ammonia (N)	
<u>15</u> () COD		<u>0.7</u> () Total Kjeldahl (N)	
<u>8.0</u> () pH		<u>0.03</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>40</u> () Susp. Solids	<u>3100</u>
<u>550</u> () Hardness		<u>6</u> () Vol. Susp. Solids	Total
() Alkalinity		<u>3060</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>14</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>73</u> Sodium %		Date results forwarded: _____	
<u>330</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: January 20, 1977Stream Name(s): Little Powder RiverSource of Sample: Site #2

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	0.5 () Lead
<0.05 () Barium	0.22 () Manganese
3.4 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.05 () Silver
() Chromium (hex)	<0.02 () Zinc
1.1 () Fluoride	<0.02 () Cyanide
0.29 () Iron (Total)	0.02 () MBAS
0.05 () Iron (Dissolved)	0.006 () Phenol (ppm)
BOD	0.9 () Oil & Grease
Fecal Coliforms 100 ml	<0.001 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected April 28, 1976 Facility Name _____

Stream Name(s) _____

Antelope Creek

Source of Sample: (Exact Location) _____

Site #1

Physical Observations, Remarks: _____

Weather Cond. Cool-Cloudy-WindyTemp. (air) 37.5 °F

Ground Cond. _____

Flow <u>6.6 cfs</u>	Field Dissolved Oxygen <u>11.1</u>	Field pH <u>8.1</u>	Field Temp. <u>39°F</u>
------------------------	---------------------------------------	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>10.73</u>	<u>220</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>6.42</u>	<u>78</u>	_____	Bicarbonate (HCO ₃)	<u>4.10</u>	<u>250</u>	_____
Sodium (Na)	<u>9.02</u>	<u>210</u>	_____	Sulfate (SO ₄)	<u>21.25</u>	<u>1000</u>	_____
Potassium (K)	<u>0.23</u>	<u>8.8</u>	_____	Chloride (Cl)	<u>0.82</u>	<u>29</u>	_____
_____	_____	_____	_____	Nitrate (NO ₃)	<u>0.00</u>	<u>0.2</u>	_____
_____	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	<u>0.05</u>	_____
_____	_____	_____	_____	Fluoride (F)	<u>0.05</u>	<u>0.9</u>	_____
Total Cations	<u>26.40</u>	_____	_____	Total Anions	<u>26.22</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>2300</u> (____) Conductance (µMHOS)	_____	<u>0.6</u> (____) Ammonia (N)	_____
<u>16</u> (____) COD	_____	<u>1.2</u> (____) Total Kjeldahl (N)	_____
<u>8.2</u> (____) pH	_____	<u>0.05</u> (____) Phosphate (PO ₄)	_____
<u>6</u> (____) Turbidity (NTU)	_____	<u>24</u> (____) Susp. Solids	_____
<u>860</u> (____) Hardness	_____	<u>12</u> (____) Vol. Susp. Solids	_____
_____ (____) Alkalinity	_____	<u>1930</u> (____) TDS	_____
_____ (____) Total Acidity	_____		_____
_____ (____) Free Acidity	_____		_____
<u>7.3</u> (____) Silica (SiO ₂)	_____		_____
<u><0.1</u> (____) Nitrite	_____		_____
<u>34</u> Sodium %	_____		_____
<u>120</u> Total CO ₂	_____		_____

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____

Date sample rec'd: _____ Time: _____

Date analysis completed: _____

Date results forwarded: _____

Total tests requested: _____ Tests run: _____

Lab Section: _____ Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: April 28, 1976Stream Name(s): Antelope CreekSource of Sample: Site #1 below Antelope Mine on Antelope Creek

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.2 () Manganese
0.10 () Boron	<0.001() Mercury
<0.01 () Cadmium	<0.1 () Nickel
0.03 () Copper	<0.001() Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.03 () Zinc
0.9 () Fluoride	<0.02 () Cyanide
0.15 () Iron (Total)	<0.01 () MBAS
() Iron (Dissolved)	<0.001() Phenol (ppm)
BOD	2.4 () Oil & Grease
Fecal Coliforms 100 ml	0.0 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected June 24, 1976 Facility Name _____

Stream Name(s) _____

Antelope Creek

Source of Sample: (Exact Location) _____

Site #1

Physical Observations, Remarks: _____

Weather Cond. Warm-ClearTemp. (air) 64 °F

Ground Cond. _____

Flow <u>2.2cfs</u>	Field Dissolved Oxygen <u>7.8 mg/l</u>	Field pH <u>8.6</u>	Field Temp. <u>70°F</u>
-----------------------	---	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>6.66</u>	<u>130</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>4.73</u>	<u>58</u>		Bicarbonate (HCO ₃)	<u>2.90</u>	<u>180</u>	
Sodium (Na)	<u>6.11</u>	<u>140</u>		Sulfate (SO ₄)	<u>14.62</u>	<u>700</u>	
Potassium (K)	<u>0.20</u>	<u>7.7</u>		Chloride (Cl)	<u>0.42</u>	<u>15</u>	
				Nitrate (NO ₃)	<u>0.01</u>	<u>0.5</u>	
				*Phosphate(PO ₄)as(P)		<u>0.04</u>	
				Fluoride (F)	<u>0.04</u>	<u>0.7</u>	
Total Cations	<u>17.70</u>			Total Anions	<u>17.99</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>1480</u> () Conductance(μMHOS)		<u>0.0</u> () Ammonia (N)	
<u>16</u> () COD		<u>1.1</u> () Total Kjeldahl (N)	
<u>8.2</u> () pH		<u>0.04</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>24</u> () Susp. Solids	<u>1220</u>
<u>570</u> () Hardness		<u>0.0</u> () Vol. Susp. Solids	Total
() Alkalinity		<u>1200</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>6.9</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>35</u> Sodium %		Date results forwarded: _____	
<u>87</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: June 24, 1976Stream Name(s): Antelope CreekSource of Sample: Site #1

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.14 () Manganese
0.03 () Boron	<0.001 () Mercury
<0.1 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.03 () Zinc
0.7 () Fluoride	() Cyanide
0.39 () Iron (Total)	0.02 () MBAS
0.15 () Iron (Dissolved)	0.002 () Phenol (ppm)
BOD	0.0 () Oil & Grease
Fecal Coliforms 100 ml	() Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected September 22, 1976 Facility Name _____

Stream Name(s) Antelope Creek
 Source of Sample: (Exact Location) Site #1

Physical Observations, Remarks: _____ Weather Cond. Warm-Clear-Windy
 Temp. (air) 55 °F
 Ground Cond. _____
 Flow 0 Field Dissolved Oxygen 7.8 Field pH 8.3 Field Temp. 54 °F

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>2.64</u>	<u>53</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>3.08</u>	<u>38</u>		Bicarbonate (HCO ₃)	<u>5.30</u>	<u>320</u>	
Sodium (Na)	<u>9.27</u>	<u>210</u>		Sulfate (SO ₄)	<u>10.08</u>	<u>480</u>	
Potassium (K)	<u>0.20</u>	<u>7.7</u>		Chloride (Cl)	<u>0.50</u>	<u>18</u>	
				Nitrate (NO ₃)	<u>0.00</u>	<u>0.0</u>	
				*Phosphate (PO ₄) as (P)		<u>0.01</u>	
				Fluoride (F)	<u>0.05</u>	<u>1.1</u>	
Total Cations	<u>15.19</u>			Total Anions	<u>15.93</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>1440</u> () Conductance (μMHOS)		<u>0.00</u> () Ammonia (N)	
<u>16</u> () COD		<u>1.4</u> () Total Kjeldahl (N)	
<u>8.0</u> () pH		<u>0.01</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>8</u> () Susp. Solids	1000 Total
<u>290</u> () Hardness		<u>8</u> () Vol. Susp. Solids	
() Alkalinity		<u>992</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>7.8</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>61</u> Sodium %		Date results forwarded: _____	
<u>160</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: September 22, 1976Stream Name(s): Antelope CreekSource of Sample: Site #1

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.01 () Lead
<0.5 () Barium	0.23 () Manganese
0.00 () Boron	<0.001() Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001() Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.02 () Zinc
1.1 () Fluoride	<0.02 () Cyanide
0.18 () Iron (Total)	<0.01 () MBAS
0.31 () Iron (Dissolved)	<0.001() Phenol (ppm)
BOD	1.0 () Oil & Grease
Fecal Coliforms 100 ml	<0.001() Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected January 19, 1977 Facility Name _____

Stream Name(s) _____

Source of Sample: (Exact Location) Antelope Creek

Site #1 _____

Physical Observations, Remarks: _____ Weather Cond. Clear-Cool

Ice 12-18" thick

Temp. (air) 42 °F

Ground Cond. _____

Flow	Field Dissolved Oxygen	Field pH	Field Temp.
0	3.6 mg/l	7.3	32°F

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	12.00	240		Carbonate (CO ₃)	0.00	0.0	
Magnesium (Mg)	8.35	100		Bicarbonate (HCO ₃)	6.04	370	
Sodium (Na)	12.53	290		Sulfate (SO ₄)	25.30	1200	
Potassium (K)	0.23	9.1		Chloride (Cl)	0.19	6.8	
				Nitrate (NO ₃)	0.00	0.2	
				*Phosphate(PO ₄)as(P)		0.03	
				Fluoride (F)	0.07	1.3	
Total Cations	33.11			Total Anions	31.60		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
2630 () Conductance(μMHOS)		0.0 () Ammonia (N)	
3.2 () COD		0.0 () Total Kjeldahl (N)	
8.0 () pH		0.01 () Phosphate (PO ₄)	
() Turbidity (NTU)		28 () Susp. Solids	2230
1000 () Hardness		4 () Vol. Susp. Solids	Total
() Alkalinity		2200 () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
11 () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<0.1 () Nitrite		Date analysis completed: _____	
38 Sodium %		Date results forwarded: _____	
180 Total CO ₂		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: January 19, 1977Stream Name(s): Antelope CreekSource of Sample: Site #1

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<u><0.05</u> () Arsenic	<u>0.2</u> () Lead
<u><0.05</u> () Barium	<u>0.94</u> () Manganese
<u>0.00</u> () Boron	<u><0.001</u> () Mercury
<u><0.01</u> () Cadmium	<u><0.1</u> () Nickel
<u><0.01</u> () Copper	<u><0.001</u> () Selenium
<u><0.1</u> () Chromium (tri)	<u><0.05</u> () Silver
<u> </u> () Chromium (hex)	<u><0.02</u> () Zinc
<u>1.3</u> () Fluoride	<u><0.02</u> () Cyanide
<u>0.05</u> () Iron (Total)	<u>0.02</u> () MBAS
<u>0.00</u> () Iron (Dissolved)	<u>0.019</u> () Phenol (ppm)
<u> </u> BOD	<u>0.7</u> () Oil & Grease
<u> </u> Fecal Coliforms 100 ml	<u>0.01</u> () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected April 28, 1976 Facility Name _____

Stream Name(s) _____

Antelope Creek

Source of Sample: (Exact Location) _____

Site #2

Physical Observations, Remarks: _____

Weather Cond. Cool-CloudyTemp. (air) 37 °F

Ground Cond. _____

Flow <u><1.0 cfs</u>	Field Dissolved Oxygen <u>10.4</u>	Field pH <u>8.1</u>	Field Temp. <u>38°F</u>
----------------------------	---------------------------------------	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>11.98</u>	<u>240</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>7.90</u>	<u>96</u>		Bicarbonate (HCO ₃)	<u>5.45</u>	<u>330</u>	
Sodium (Na)	<u>10.77</u>	<u>250</u>		Sulfate (SO ₄)	<u>24.93</u>	<u>1200</u>	
Potassium (K)	<u>0.35</u>	<u>14</u>		Chloride (Cl)	<u>0.71</u>	<u>25</u>	
				Nitrate (NO ₃)	<u>0.00</u>	<u>0.2</u>	
				*Phosphate (PO ₄) as (P)		<u>0.06</u>	
				Fluoride (F)	<u>0.05</u>	<u>1.0</u>	
Total Cations	<u>31.00</u>			Total Anions	<u>31.14</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>2620</u> () Conductance (µMHOS)		<u>0.0</u> () Ammonia (N)	
<u>12</u> () COD		<u>0.5</u> () Total Kjeldahl (N)	
<u>8.2</u> () pH		<u>0.06</u> () Phosphate (PO ₄)	
<u>14</u> () Turbidity (NTU)		<u>56</u> () Susp. Solids	<u>2340</u>
<u>990</u> () Hardness		<u>12</u> () Vol. Susp. Solids	Total
() Alkalinity		<u>2280</u> () TDS	
() Total Acidity			
() Free Acidity			
<u>10</u> () Silica (SiO ₂)			
<u><0.1</u> () Nitrite			
<u>35</u> Sodium %			
<u>160</u> Total CO ₂			

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____

Date sample rec'd: _____ Time: _____

Date analysis completed: _____

Date results forwarded: _____

Total tests requested: _____ Tests run: _____

Lab Section: _____ Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: April 28, 1976Stream Name(s): Antelope CreekSource of Sample: Site #2 above Fiddleback Ranch on Antelope Creek

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.2 () Manganese
0.08 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
0.03 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
1.0 () Chromium (hex)	0.03 () Zinc
() Fluoride	<0.02 () Cyanide
0.11 () Iron (Total)	<0.01 () MBAS
() Iron (Dissolved)	0.005 () Phenol (ppm)
BOD	1.4 () Oil & Grease
Fecal Coliforms 100 ml	0.0 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected June 24, 1976 Facility Name _____

Stream Name(s) _____

Antelope Creek

Source of Sample: (Exact Location) _____

Site #2

Physical Observations, Remarks: _____

Weather Cond. Warm-ClearTemp. (air) 65 °F

Ground Cond. _____

Flow <u>24.0 cfs</u>	Field Dissolved Oxygen <u>7.2 mg/l</u>	Field pH <u>8.4</u>	Field Temp. <u>70°F</u>
-------------------------	---	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>6.06</u>	<u>120</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>3.78</u>	<u>46</u>		Bicarbonate (HCO ₃)	<u>2.75</u>	<u>170</u>	
Sodium (Na)	<u>6.11</u>	<u>140</u>		Sulfate (SO ₄)	<u>11.74</u>	<u>560</u>	
Potassium (K)	<u>0.23</u>	<u>9.1</u>		Chloride (Cl)	<u>0.37</u>	<u>13</u>	
				Nitrate (NO ₃)	<u>0.02</u>	<u>1.2</u>	
				*Phosphate (PO ₄) as (P)		<u>0.19</u>	
				Fluoride (F)	<u>0.04</u>	<u>0.8</u>	
Total Cations	<u>16.18</u>			Total Anions	<u>14.92</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>790</u> () Conductance (μMHOS)		<u>0.0</u> () Ammonia (N)	
<u>16</u> () COD		<u>2.0</u> () Total Kjeldahl (N)	
<u>8.0</u> () pH		<u>0.19</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>1020</u> () Susp. Solids	<u>2020</u> Total
<u>490</u> () Hardness		<u>88</u> () Vol. Susp. Solids	
() Alkalinity		<u>996</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>9.5</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>38</u> Sodium %		Date results forwarded: _____	
<u>82</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: June 24, 1976Stream Name(s): Antelope CreekSource of Sample: Site #2

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.00 () Manganese
0.02 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.03 () Zinc
0.8 () Fluoride	() Cyanide
3.88 () Iron (Total)	0.02 () MBAS
1.60 () Iron (Dissolved)	<0.001 () Phenol (ppm)
BOD	0.0 () Oil & Grease
Fecal Coliforms 100 ml	() Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected September 21, 1976 Facility Name _____

Stream Name(s) _____

Antelope Creek

Source of Sample: (Exact Location) _____

Site #2

Physical Observations, Remarks: _____

Weather Cond. Cear-Warm-
CalmTemp. (air) 65 °F

Ground Cond. _____

Flow <u><0.5 cfs</u>	Field Dissolved Oxygen <u>-</u>	Field pH <u>8.1</u>	Field Temp. <u>71°F</u>
----------------------------	------------------------------------	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>11.53</u>	<u>230</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>8.80</u>	<u>110</u>		Bicarbonate (HCO ₃)	<u>5.25</u>	<u>320</u>	
Sodium (Na)	<u>12.27</u>	<u>280</u>		Sulfate (SO ₄)	<u>27.71</u>	<u>1300</u>	
Potassium (K)	<u>0.40</u>	<u>16</u>		Chloride (Cl)	<u>0.71</u>	<u>25</u>	
				Nitrate (NO ₃)	<u>0.02</u>	<u>1.0</u>	
				*Phosphate(PO ₄)as(P)		<u>0.04</u>	
				Fluoride (F)	<u>0.05</u>	<u>1.0</u>	
Total Cations	<u>33.00</u>			Total Anions	<u>33.74</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>2780</u> () Conductance(μMHOS)		<u>0.0</u> () Ammonia (N)	
<u>12</u> () COD		<u>1.1</u> () Total Kjeldahl (N)	
<u>8.1</u> () pH		<u>0.04</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>20</u> () Susp. Solids	<u>2450</u>
<u>1000</u> () Hardness		<u>20</u> () Vol. Susp. Solids	Total
() Alkalinity		<u>2430</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>13</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>37</u> Sodium %		Date results forwarded: _____	
<u>160</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: September 21, 1976Stream Name(s): Antelope CreekSource of Sample: Site #2

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<0.05 () Arsenic	0.2 () Lead
<0.5 () Barium	0.12 () Manganese
0.00 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	<0.02 () Zinc
1.0 () Fluoride	<0.02 () Cyanide
0.00 () Iron (Total)	<0.01 () MBAS
0.00 () Iron (Dissolved)	<0.001 () Phenol (ppm)
BOD	0.9 () Oil & Grease
Fecal Coliforms 100 ml	<0.001 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected May 13, 1976 Facility Name _____

Stream Name(s) _____
School Creek
 Source of Sample: (Exact Location) _____

Physical Observations, Remarks: Instream - clear			Weather Cond. <u>Clear-Warm</u>
			Temp. (air) <u>65</u> °F
			Ground Cond. _____
Flow <u><0.5 cfs</u>	Field Dissolved Oxygen <u>4.6 mg/l</u>	Field pH <u>7.8</u>	Field Temp. <u>46°F</u>

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>20.21</u>	<u>410</u>	_____	Carbonate (CO ₃)	<u>0.94</u>	<u>28</u>	_____
Magnesium (Mg)	<u>21.22</u>	<u>260</u>	_____	Bicarbonate (HCO ₃)	<u>9.16</u>	<u>560</u>	_____
Sodium (Na)	<u>14.32</u>	<u>330</u>	_____	Sulfate (SO ₄)	<u>50.03</u>	<u>2400</u>	_____
Potassium (K)	<u>1.07</u>	<u>42</u>	_____	Chloride (Cl)	<u>0.90</u>	<u>32</u>	_____
	_____	_____	_____	Nitrate (NO ₃)	<u>0.01</u>	<u>0.8</u>	_____
	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	<u>0.01</u>	_____
	_____	_____	_____	Fluoride (F)	<u>0.08</u>	<u>1.4</u>	_____
Total Cations	<u>56.82</u>	_____	_____	Total Anions	<u>61.12</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>3660</u> () Conductance (μMHOS)	_____	<u>0.0</u> () Ammonia (N)	_____
<u>66</u> () COD	_____	<u>1.1</u> () Total Kjeldahl (N)	_____
<u>8.5</u> () pH	_____	<u>0.01</u> () Phosphate (PO ₄)	_____
<u>3.5</u> () Turbidity (NTU)	_____	<u>44</u> () Susp. Solids	_____
<u>2100</u> () Hardness	_____	<u>36</u> () Vol. Susp. Solids	_____
() Alkalinity	_____	<u>4030</u> () TDS	_____
() Total Acidity	_____		_____
() Free Acidity	_____		_____
<u>12</u> () Silica (SiO ₂)	_____		_____
<u><0.1</u> () Nitrite	_____		_____
<u>25</u> Sodium %	_____		_____
<u>2100</u> Total CO ₃	_____		_____

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____
 Date sample rec'd: _____ Time: _____
 Date analysis completed: _____
 Date results forwarded: _____
 Total tests requested: _____ Tests run: _____
 Lab Section: _____ Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: May 13, 1976Stream Name(s): School Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.33 () Manganese
1.08 () Boron	<0.001() Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001() Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.19 () Zinc
1.4 () Fluoride	<0.02 () Cyanide
0.7 () Iron (Total)	() MBAS
() Iron (Dissolved)	0.009() Phenol (ppm)
BOD	0.0 () Oil & Grease
Fecal Coliforms 100 ml	0.0 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected June 24, 1976 Facility Name _____

Stream Name(s) _____

Source of Sample: (Exact Location) School Creek

Physical Observations, Remarks:			Weather Cond. <u>Clear-Cool-Windy</u>
			Temp. (air) <u>54</u> °F
			Ground Cond. _____
Flow <u>≤0.5 cfs</u>	Field Dissolved Oxygen <u>4.2 mg/l</u>	Field pH <u>7.6</u>	Field Temp. <u>55°F</u>

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>18.09</u>	<u>360</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>17.48</u>	<u>210</u>		Bicarbonate (HCO ₃)	<u>8.60</u>	<u>520</u>	
Sodium (Na)	<u>12.29</u>	<u>280</u>		Sulfate (SO ₄)	<u>37.44</u>	<u>1800</u>	
Potassium (K)	<u>0.74</u>	<u>29</u>		Chloride (Cl)	<u>0.71</u>	<u>25</u>	
				Nitrate (NO ₃)	<u>0.01</u>	<u>0.5</u>	
				*Phosphate (PO ₄) as (P)		<u>0.04</u>	
				Fluoride (F)	<u>0.07</u>	<u>1.4</u>	
Total Cations	<u>48.60</u>			Total Anions	<u>46.83</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>3040</u> () Conductance (μMHOS)		<u>0.0</u> () Ammonia (N)	
<u>67</u> () COD		<u>1.8</u> () Total Kjeldahl (N)	
<u>8.1</u> () pH		<u>0.04</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>20</u> () Susp. Solids	3180 Total
<u>1800</u> () Hardness		<u>4.0</u> () Vol. Susp. Solids	
() Alkalinity		<u>3160</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>11</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>25</u> Sodium %		Date results forwarded: _____	
<u>260</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: June 24, 1976Stream Name(s): School Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.18 () Manganese
0.84 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.02 () Zinc
1.4 () Fluoride	<0.02 () Cyanide
1.17 () Iron (Total)	0.03 () MBAS
0.00 () Iron (Dissolved)	<0.001 () Phenol (ppm)
BOD	0.0 () Oil & Grease
Fecal Coliforms 100 ml	<0.001 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected September 22, 1976 Facility Name _____

Stream Name(s) _____

School Creek

Source of Sample: (Exact Location) _____

Physical Observations, Remarks: _____ Weather Cond. Clear-Warm-WindyTemp. (air) 70 °F
Ground Cond. _____Flow 0 Field Dissolved Oxygen 3.9 mg/l Field pH 8.1 Field Temp. 64°F

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>28.54</u>	<u>570</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>54.29</u>	<u>660</u>		Bicarbonate (HCO ₃)	<u>9.10</u>	<u>560</u>	
Sodium (Na)	<u>42.88</u>	<u>990</u>		Sulfate (SO ₄)	<u>115.15</u>	<u>5500</u>	
Potassium (K)	<u>2.08</u>	<u>82</u>		Chloride (Cl)	<u>2.57</u>	<u>91</u>	
				Nitrate (NO ₃)	<u>0.00</u>	<u>0.00</u>	
				*Phosphate (PO ₄) as (P)		<u>0.17</u>	
				Fluoride (F)	<u>0.30</u>	<u>5.7</u>	
Total Cations	<u>127.79</u>			Total Anions	<u>127.12</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>8290</u> () Conductance (μMHOS)		<u>0.0</u> () Ammonia (N)	
<u>170</u> () COD		<u>6.6</u> () Total Kjeldahl (N)	
<u>7.7</u> () pH		<u>0.17</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>128</u> () Susp. Solids	9770 Total
<u>4100</u> () Hardness		<u>8</u> () Vol. Susp. Solids	
() Alkalinity		<u>9760</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>2.7</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>34</u> Sodium %		Date results forwarded: _____	
<u>270</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: September 22, 1976Stream Name(s): School Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<0.05 () Arsenic	0.4 () Lead
<0.5 () Barium	5.34 () Manganese
4.43 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	0.001 () Selenium
<0.1 () Chromium (tri)	0.5 () Silver
() Chromium (hex)	0.02 () Zinc
5.7 () Fluoride	<0.02 () Cyanide
0.00 () Iron (Total)	() MBAS
0.00 () Iron (Dissolved)	0.015 () Phenol (ppm)
BOD	2.3 () Oil & Grease
Fecal Coliforms 100 ml	0.006 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected January 19, 1977 Facility Name _____

Stream Name(s) _____

School Creek

Source of Sample: (Exact Location) _____

Physical Observations, Remarks:
Ice 18" thick

Weather Cond. Clear-Cold

Temp. (air) 37.5 °F
 Ground Cond. _____

Flow 0	Field Dissolved Oxygen 2.2 mg/l	Field pH 7.3	Field Temp. 32°F
-----------	------------------------------------	-----------------	---------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	25.45	510		Carbonate (CO ₃)	0.00	0.0	
Magnesium (Mg)	26.73	330		Bicarbonate (HCO ₃)	14.40	880	
Sodium (Na)	16.80	390		Sulfate (SO ₄)	55.09	2600	
Potassium (K)	0.45	17		Chloride (Cl)	0.12	4.3	
				Nitrate (NO ₃)	0.03	1.6	
				*Phosphate (PO ₄) as (P)	0.01	0.06	
				Fluoride (F)	0.18	3.4	
Total Cations	69.43			Total Anions	69.82		

Values reported are mg/l unless otherwise stated.

*Not included in Total Anions.

This Test	Base Average	This Test	Base Average
4820 () Conductance (μMHOS)		0.0 () Ammonia (N)	
62 () COD		2.2 () Total Kjeldahl (N)	
7.8 () pH		0.01 () Phosphate (PO ₄)	
() Turbidity (NTU)		68 () Susp. Solids	4750 Total
2600 () Hardness		12 () Vol. Susp. Solids	
() Alkalinity		4680 () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
16 () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<0.1 () Nitrite		Date analysis completed: _____	
24 Sodium %		Date results forwarded: _____	
430 Total CO ₂		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: January 19, 1977Stream Name(s): School Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base
& Time Test Average

Preservative This Base
& Time Test Average

<0.05 () Arsenic	0.6 () Lead
<0.5 () Barium	5.81 () Manganese
10 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.05 () Silver
() Chromium (hex)	<0.02 () Zinc
3.4 () Fluoride	<0.02 () Cyanide
3.40 () Iron (Total)	0.04 () MBAS
2.62 () Iron (Dissolved)	0.012 () Phenol (ppm)
BOD	2.5 () Oil & Grease
Fecal Coliforms 100 ml	0.01 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected May 13, 1976 Facility Name _____

Stream Name(s) _____

Little Thunder Creek

Source of Sample: (Exact Location) _____

Physical Observations, Remarks: _____

Weather Cond. Clear-WarmTemp. (air) 74 °F
Ground Cond. _____

Flow <u><1.0 cfs</u>	Field Dissolved Oxygen <u>8.5 mg/l</u>	Field pH <u>8.0</u>	Field Temp. <u>55°F</u>
----------------------------	---	------------------------	----------------------------

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>7.73</u>	<u>160</u>	_____	Carbonate (CO ₃)	<u>1.00</u>	<u>30</u>	_____
Magnesium (Mg)	<u>8.18</u>	<u>100</u>	_____	Bicarbonate (HCO ₃)	<u>4.53</u>	<u>280</u>	_____
Sodium (Na)	<u>7.69</u>	<u>180</u>	_____	Sulfate (SO ₄)	<u>20.05</u>	<u>960</u>	_____
Potassium (K)	<u>0.40</u>	<u>16</u>	_____	Chloride (Cl)	<u>0.35</u>	<u>12</u>	_____
_____	_____	_____	_____	Nitrate (NO ₃)	<u>0.00</u>	<u>0.2</u>	_____
_____	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	<u>0.01</u>	_____
_____	_____	_____	_____	Fluoride (F)	<u>0.05</u>	<u>0.9</u>	_____
Total Cations	<u>24.00</u>	_____	_____	Total Anions	<u>25.98</u>	_____	_____

Values reported are mg/l unless other- *Not included in Total Anions.
 wise stated.

This Test	Base Average	This Test	Base Average
<u>1930</u> (____) Conductance (μMHOS)	_____	<u>0.0</u> (____) Ammonia (N)	_____
<u>21</u> (____) COD	_____	<u>0.7</u> (____) Total Kjeldahl (N)	_____
<u>8.6</u> (____) pH	_____	<u>0.01</u> (____) Phosphate (PO ₄)	_____
<u>13</u> (____) Turbidity (NTU)	_____	<u>52</u> (____) Susp. Solids	_____
<u>800</u> (____) Hardness	_____	<u>40</u> (____) Vol. Susp. Solids	_____
_____ (____) Alkalinity	_____	<u>1660</u> (____) TDS	_____
_____ (____) Total Acidity	_____		_____
_____ (____) Free Acidity	_____		_____
<u>7.6</u> (____) Silica (SiO ₂)	_____		_____
<u><0.1</u> (____) Nitrite	_____		_____
<u>32</u> Sodium %	_____		_____
<u>170</u> Total CO ₃	_____		_____

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____
 Date sample rec'd: _____ Time: _____
 Date analysis completed: _____
 Date results forwarded: _____
 Total tests requested: _____ Tests run: _____
 Lab Section: _____ Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: May 13, 1976Stream Name(s): Little Thunder Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.00 () Manganese
0.32 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	0.40 () Zinc
0.9 () Fluoride	<0.02 () Cyanide
0.07 () Iron (Total)	() MBAS
() Iron (Dissolved)	<0.001 () Phenol (ppm)
BOD	0.0 () Oil & Grease
Fecal Coliforms 100 ml	0.0 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected June 24, 1976 Facility Name _____

Stream Name(s) _____

Source of Sample: (Exact Location) Little Thunder Creek

Physical Observations, Remarks:			Weather Cond. <u>Clear-Warm-Windy</u>
			Temp. (air) <u>68</u> °F
			Ground Cond. _____
Flow <u>1.4 cfs</u>	Field Dissolved Oxygen <u>5.4 mg/l</u>	Field pH <u>7.6</u>	Field Temp. <u>61°F</u>

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>4.29</u>	<u>86</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>3.39</u>	<u>41</u>	_____	Bicarbonate (HCO ₃)	<u>3.50</u>	<u>210</u>	_____
Sodium (Na)	<u>3.65</u>	<u>84</u>	_____	Sulfate (SO ₄)	<u>7.52</u>	<u>360</u>	_____
Potassium (K)	<u>0.23</u>	<u>8.8</u>	_____	Chloride (Cl)	<u>0.16</u>	<u>5.6</u>	_____
	_____	_____	_____	Nitrate (NO ₃)	<u>0.01</u>	<u>0.7</u>	_____
	_____	_____	_____	*Phosphate (PO ₄) as (P)	_____	_____	_____
	_____	_____	_____	Fluoride (F)	<u>0.03</u>	<u>0.6</u>	_____
Total Cations	<u>11.56</u>	_____	_____	Total Anions	<u>11.22</u>	_____	_____

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>981</u> ()	Conductance(μMHOS)	<u>0.0</u> ()	Ammonia (N)
<u>20</u> ()	COD	<u>1.4</u> ()	Total Kjeldahl (N)
<u>8.0</u> ()	pH	()	Phosphate (PO ₄)
()	Turbidity (NTU)	<u>68</u> ()	Susp. Solids
<u>380</u> ()	Hardness	<u>8.0</u> ()	Vol. Susp. Solids
()	Alkalinity	<u>738</u> ()	TDS
()	Total Acidity	FOR LAB USE ONLY	
()	Free Acidity	Lab Number: _____	Rec'd by: _____
<u>8.6</u> ()	Silica (SiO ₂)	Date sample rec'd: _____	Time: _____
<u><0.1</u> ()	Nitrite	Date analysis completed: _____	
<u>32</u>	Sodium %	Date results forwarded: _____	
<u>100</u>	Total CO ₃	Total tests requested: _____	Tests run: _____
		Lab Section: _____	Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: June 24, 1976Stream Name(s): Little Thunder Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	0.18 () Manganese
0.14 () Boron	<0.001() Mercury
<0.01 () Cadmium	<0.1 () Nickel
() Copper	<0.001() Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	<0.02 () Zinc
0.6 () Fluoride	<0.02 () Cyanide
0.63 () Iron (Total)	<0.01 () MBAS
0.19 () Iron (Dissolved)	0.005() Phenol (ppm)
BOD	2.0 () Oil & Grease
Fecal Coliforms 100 ml	<0.001() Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector WescheDate Collected September 22, 1976 Facility Name _____

Stream Name(s) _____

Little Thunder Creek

Source of Sample: (Exact Location) _____

Physical Observations, Remarks:			Weather Cond. <u>Clear-Warm</u> <u>Windy</u>
			Temp. (air) <u>76</u> °F
			Ground Cond. _____
Flow <u>0</u>	Field Dissolved Oxygen <u>10.0 mg/l</u>	Field pH <u>8.3</u>	Field Temp. <u>68°F</u>

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>6.04</u>	<u>120</u>		Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	
Magnesium (Mg)	<u>8.68</u>	<u>110</u>		Bicarbonate (HCO ₃)	<u>4.55</u>	<u>280</u>	
Sodium (Na)	<u>7.87</u>	<u>180</u>		Sulfate (SO ₄)	<u>19.45</u>	<u>930</u>	
Potassium (K)	<u>0.48</u>	<u>19</u>		Chloride (Cl)	<u>0.36</u>	<u>13</u>	
				Nitrate (NO ₃)	<u>0.00</u>	<u>0.0</u>	
				*Phosphate (PO ₄) as (P)		<u>0.03</u>	
				Fluoride (F)	<u>0.05</u>	<u>0.9</u>	
Total Cations	<u>23.07</u>			Total Anions	<u>24.41</u>		

Values reported are mg/l unless otherwise stated. *Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>2020</u> () Conductance (μMHOS)		<u>0.0</u> () Ammonia (N)	
<u>19</u> () COD		<u>1.1</u> () Total Kjeldahl (N)	
<u>8.1</u> () pH		<u>0.03</u> () Phosphate (PO ₄)	
() Turbidity (NTU)		<u>28</u> () Susp. Solids	<u>1700</u>
<u>740</u> () Hardness		<u>28</u> () Vol. Susp. Solids	Total
() Alkalinity		<u>1670</u> () TDS	
() Total Acidity		FOR LAB USE ONLY	
() Free Acidity		Lab Number: _____ Rec'd by: _____	
<u>6.8</u> () Silica (SiO ₂)		Date sample rec'd: _____ Time: _____	
<u><0.1</u> () Nitrite		Date analysis completed: _____	
<u>34</u> Sodium %		Date results forwarded: _____	
<u>140</u> Total CO ₃		Total tests requested: _____ Tests run: _____	
		Lab Section: _____ Supervisor: _____	

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: September 22, 1976

Stream Name(s): Little Thunder Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	<0.1 () Lead
<0.5 () Barium	<0.05 () Manganese
0.32 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.5 () Silver
() Chromium (hex)	<0.02 () Zinc
0.9 () Fluoride	<0.02 () Cyanide
0.00 () Iron (Total)	<0.01 () MBAS
0.00 () Iron (Dissolved)	0.01 () Phenol (ppm)
BOD	0.0 () Oil & Grease
Fecal Coliforms 100 ml	<0.001 () Sulfides

SPECIAL INSTRUCTIONS

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 1 of 2)

Time Collected _____ Collector Wesche
 Date Collected January 19, 1977 Facility Name _____

Stream Name(s) _____
Little Thunder Creek
 Source of Sample: (Exact Location) _____

Physical Observations, Remarks: <u>Ice 18" thick</u>		Weather Cond. <u>Clear-Cool</u>	
		Temp. (air) <u>35</u> °F	
		Ground Cond. _____	
Flow <u>0</u>	Field Dissolved Oxygen <u>6.0 mg/l</u>	Field pH <u>7.3</u>	Field Temp. <u>31°F</u>

CATIONS	meq/l	mg/l	(Base Average)	ANIONS	meq/l	mg/l	(Base Average)
Calcium (Ca)	<u>9.91</u>	<u>200</u>	_____	Carbonate (CO ₃)	<u>0.00</u>	<u>0.0</u>	_____
Magnesium (Mg)	<u>8.23</u>	<u>100</u>	_____	Bicarbonate (HCO ₃)	<u>6.80</u>	<u>410</u>	_____
Sodium (Na)	<u>8.20</u>	<u>190</u>	_____	Sulfate (SO ₄)	<u>17.59</u>	<u>850</u>	_____
Potassium (K)	<u>0.40</u>	<u>16</u>	_____	Chloride (Cl)	<u>0.10</u>	<u>3.4</u>	_____
	_____	_____	_____	Nitrate (NO ₃)	<u>0.01</u>	<u>0.3</u>	_____
	_____	_____	_____	*Phosphate (PO ₄) as (P)	<u>0.01</u>	<u>0.04</u>	_____
	_____	_____	_____	Fluoride (F)	<u>0.06</u>	<u>1.1</u>	_____
Total Cations	<u>26.74</u>	_____	_____	Total Anions	<u>24.56</u>	_____	_____

Values reported are mg/l unless otherwise stated.

*Not included in Total Anions.

This Test	Base Average	This Test	Base Average
<u>2040</u> (____) Conductance (μMHOS)	_____	<u>0.0</u> (____) Ammonia (N)	_____
<u>2.3</u> (____) COD	_____	<u>0.6</u> (____) Total Kjeldahl (N)	_____
<u>8.0</u> (____) pH	_____	<u>0.01</u> (____) Phosphate (PO ₄)	_____
(____) Turbidity (NTU)	_____	<u>44</u> (____) Susp. Solids	_____
<u>910</u> (____) Hardness	_____	<u>4</u> (____) Vol. Susp. Solids	_____
(____) Alkalinity	_____	<u>1630</u> (____) TDS	_____
(____) Total Acidity	_____		_____
(____) Free Acidity	_____		_____
<u>23</u> (____) Silica (SiO ₂)	_____		_____
<u><0.1</u> (____) Nitrite	_____		_____
<u>31</u> Sodium %	_____		_____
<u>200</u> Total CO ₃	_____		_____

FOR LAB USE ONLY

Lab Number: _____ Rec'd by: _____
 Date sample rec'd: _____ Time: _____
 Date analysis completed: _____
 Date results forwarded: _____
 Total tests requested: _____ Tests run: _____
 Lab Section: _____ Supervisor: _____

Transported by: _____

Transported by: _____

Received by: _____

Received by: _____

University of Wyoming - Water Resources Research Institute

Water Analysis Form (Page 2 of 2)

Time Collected: _____

Date Collected: January 19, 1977Stream Name(s): Little Thunder Creek

Source of Sample: _____

Special sampling and testing procedures are required for these water tests. Indicate on form if preservative has been added to sample and time tests were completed.

(Values reported are mg/l unless otherwise stated.)

Preservative This Base & Time Test Average	Preservative This Base & Time Test Average
<0.05 () Arsenic	0.3 () Lead
<0.5 () Barium	1.28 () Manganese
2.4 () Boron	<0.001 () Mercury
<0.01 () Cadmium	<0.1 () Nickel
<0.01 () Copper	<0.001 () Selenium
<0.1 () Chromium (tri)	<0.05 () Silver
() Chromium (hex)	<0.02 () Zinc
1.1 () Fluoride	<0.02 () Cyanide
0.10 () Iron (Total)	0.02 () MBAS
0.00 () Iron (Dissolved)	0.008 () Phenol (ppm)
BOD	0.8 () Oil & Grease
Fecal Coliforms 100 ml	<0.001 () Sulfides

SPECIAL INSTRUCTIONS

Appendix E

WATER QUALITY DATA SUMMARY

TABLE E-1

LITTLE POWDER RIVER WATER QUALITY DATA

Water Quality Parameter (mg/l unless specified)	4-28-76		6-23-76		9-23-76		1-20-77	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Calcium (Ca)	210	93	76	54	340	320	180	130
Magnesium (Mg)	110	27	38	28	170	170	110	52
Sodium (Na)	350	370	130	120	250	290	770	720
Potassium (K)	19	9.1	10	8.1	42	42	13	14
Total Cations (meq/l)	35.14	23.16	12.71	10.42	43.04	44.17	52.17	42.85
Carbonate (CO_3)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (HCO_3)	470	400	220	190	290	310	720	670
Sulfate (SO_4)	1300	870	420	340	1900	1800	1700	1600
Chloride (Cl)	14	13	7.4	7.4	9.6	9.3	2.9	33
Nitrate (NO_3)	0.4	0.5	1.5	1.5	0.0	0.0	0.5	0.8
Phosphate (PO_4) as (P)	0.05	0.05	0.14	0.14	0.02	0.02	0.02	0.04
Fluoride (F)	1.0	0.8	0.4	0.3	1.1	1.2	1.2	1.1
Total Anions (meq/l)	34.59	25.11	12.50	10.29	45.19	43.53	47.68	43.80
Conductance (μmhos)	2840	2260	1110	970	3250	3410	4040	3780
COD	27	27	25	25	14	13	16	15
pH (SU)	8.3	8.3	7.9	7.8	8.0	8.1	8.0	8.0
Turbidity (NTU)	40	80	315	380	6.5	14.0	--	--
Hardness (CaCO_3)	980	340	340	250	1600	1500	920	550
Silica (SiO_2)	7.0	7.5	13	13	4.8	2.4	13	14
Nitrite	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.01	<0.1
Sodium %	43	69	44	50	25	29	64	73
Total CO_3	230	200	110	91	140	150	350	330
Ammonia (N)	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total Kjeldahl (N)	1.8	1.4	1.8	2.1	1.1	0.7	0.6	0.7
Phosphate (PO_4)	0.05	0.05	0.14	0.14	0.02	0.02	0.02	0.03
Suspended Solids	84	104	590	560	24	12	40	40
Vol. Suspended Solids	16	12	50	50	24	12	8	6
TDS	2410	1680	872	816	3250	3260	3270	3060
Total Solids	2490	1780	1460	1380	3270	3270	3310	3100

TABLE E-1 (Cont.)

Water Quality Parameter (mg/l unless specified)	4-28-76		6-23-76		9-23-76		1-20-77	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
Arsenic	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.05
Boron	0.45	0.15	0.14	0.12	2.09	3.97	3.2	3.4
Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.03	<0.01
Copper	0.03	0.03	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	<0.1	<0.1	<0.01	<0.1	<0.01	<0.1	<0.1	<0.1
Fluoride	1.0	0.8	0.4	0.3	1.1	1.2	1.2	1.1
Iron (Total)	0.48	0.26	2.86	4.22	0.00	0.00	0.44	0.29
Iron (Dissolved)	--	--	1.55	0.63	0.00	0.00	0.00	0.05
Lead	<0.1	<0.1	<0.1	<0.1	0.2	0.3	0.6	0.5
Manganese	0.2	0.2	0.07	0.18	<0.05	<0.05	0.59	0.22
Mercury	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.05	<0.05
Zinc	0.03	0.13	0.03	0.34	<0.02	<0.02	<0.02	<0.02
Cyanide	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
MBAS	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	<0.02
Phenol (ppm)	0.003	0.003	0.002	0.004	<0.001	<0.001	0.006	0.006
Oil and Grease	1.7	1.6	1.3	0.4	1.3	1.2	1.1	0.9
Sulfides	0.0	0.0	<0.001	<0.001	<0.001	<0.001	0.002	<0.001

TABLE E-2
ANTELOPE CREEK WATER QUALITY DATA

Water Quality Parameter (mg/l unless specified)	4-28-76		6-24-76		9-22-76		1-19-77
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1
Calcium (Ca)	220	240	130	120	53	230	240
Magnesium (Mg)	78	96	58	46	38	110	100
Sodium (Na)	210	250	140	140	210	280	290
Potassium (K)	8.8	14	7.7	9.1	7.7	16	9.1
Total Cations (meq/l)	26.40	31.00	17.70	16.18	15.19	33.00	33.11
Carbonate (CO ₃)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (HCO ₃)	250	330	180	170	370	320	370
Sulfate (SO ₄)	1000	1200	700	560	480	1300	1200
Chloride (Cl)	29	25	15	13	18	25	6.8
Nitrate (NO ₃)	0.2	0.2	0.5	1.2	0.0	1.0	0.2
Phosphate (PO ₄) as (P)	0.05	0.06	0.04	0.19	0.01	0.04	0.03
Fluoride (F)	0.9	1.0	0.7	0.8	1.1	1.0	1.3
Total Anions (meq/l)	26.22	31.14	17.99	14.92	15.93	33.74	31.60
Conductance (µmhos)	2300	2620	1480	790	1440	2780	2630
COD	16	12	16	16	16	12	3.2
pH (SU)	8.2	8.2	8.2	8.0	8.0	8.1	8.0
Turbidity (NTU)	6	14	1.3	450	2.4	2.5	--
Hardness (CaCO ₃)	860	990	570	490	290	1000	1000
Silica (SiO ₂)	7.3	10	6.9	9.5	7.8	13	11
Nitrite	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Sodium %	34	35	35	38	61	37	38
Total CO ₃	120	160	87	82	160	160	180
Ammonia (N)	0.6	0.0	0.0	0.0	0.0	0.0	0.0
Total Kjeldahl (N)	1.2	0.5	1.1	2.0	1.4	1.1	0.0
Phosphate (PO ₄)	0.05	0.06	0.04	0.19	0.01	0.04	0.01
Suspended Solids	24	56	24	1020	8	20	28
Vol. Suspended Solids	12	12	0.0	88	8	20	4
TDS	1930	2280	1200	996	992	2430	2200
Total Solids	1950	2340	1220	2020	1000	2450	2230

TABLE E-2 (Cont.)

Water Quality Parameter (mg/l unless specified)	4-28-76		6-24-76		9-22-76		1-19-77
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1
Arsenic	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Barium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.05
Boron	0.10	0.08	0.03	0.02	0.00	0.00	0.00
Cadmium	<0.01	<0.01	<0.1	<0.01	<0.01	<0.01	<0.01
Copper	0.03	0.03	<0.01	<0.01	<0.01	<0.01	<0.01
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Fluoride	0.9	1.0	0.7	0.8	1.1	1.0	1.3
Iron (Total)	0.15	0.11	0.39	3.88	0.18	0.00	0.05
Iron (Dissolved)	--	--	0.15	1.60	0.31	0.00	0.00
Lead	<0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.2
Manganese	0.2	0.2	0.14	0.00	0.23	0.12	0.94
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.05
Zinc	0.03	0.03	0.03	0.03	0.02	<0.02	<0.02
Cyanide	<0.02	<0.02	--	--	<0.02	<0.02	<0.02
MBAS	<0.01	<0.01	0.02	0.02	<0.01	<0.01	0.02
Phenol (ppm)	<0.001	0.005	0.002	<0.001	<0.001	<0.001	0.19
Oil and Grease	2.4	1.4	0.0	0.0	1.0	0.9	0.7
Sulfides	0.0	0.0	--	--	<0.001	<0.001	0.01

TABLE E-3
SCHOOL CREEK WATER QUALITY DATA

Water Quality Parameter (mg/l unless specified)	5-13-76	6-24-76	9-22-76	1-19-77
Calcium (Ca)	410	360	570	510
Magnesium (Mg)	260	210	660	330
Sodium (Na)	330	280	990	390
Potassium (K)	42	29	82	17
Total Cations (meq/l)	56.82	48.60	127.79	69.43
Carbonate (CO ₃)	28	0.0	0.0	0.0
Bicarbonate (HCO ₃)	560	520	560	880
Sulfate (SO ₄)	2400	1800	5500	2600
Chloride (Cl)	32	25	91	4.3
Nitrate (NO ₃)	0.8	0.5	0.00	1.6
Phosphate (PO ₄) as (P)	0.01	0.04	0.17	0.06
Fluoride (F)	1.4	1.4	5.7	3.4
Total Anions (meq/l)	61.12	46.83	127.12	69.82
Conductance (μmhos)	3660	3040	8290	4820
COD	66	67	170	62
pH (SU)	8.5	8.1	7.7	7.8
Turbidity (NTU)	3.5	2.3	19.0	--
Hardness (CaCO ₃)	2100	1800	4100	2600
Silica (SiO ₂)	12	11	2.7	16
Nitrite	<0.1	<0.1	<0.1	<0.1
Sodium %	25	25	34	24
Total CO ₃	2100	260	270	430
Ammonia (N)	0.0	0.0	0.0	0.0
Total Kjeldahl (N)	1.1	1.8	6.6	2.2
Phosphate (PO ₄)	0.01	0.04	0.17	0.01
Suspended Solids	44	20	128	68
Vol. Suspended Solids	36	4.0	8	12
TDS	4030	3160	9760	4680
Total Solids	4070	3180	9770	4750

TABLE E-3 (Cont.)

Water Quality Parameter (mg/l unless specified)	5-13-76	6-24-76	9-22-76	1-19-77
Arsenic	<0.05	<0.05	<0.05	<0.05
Barium	<0.5	<0.5	<0.5	<0.5
Boron	1.08	0.84	4.43	10
Cadmium	<0.01	<0.01	<0.01	<0.01
Copper	<0.01	<0.01	<0.01	<0.01
Chromium	<0.1	<0.1	<0.1	<0.1
Fluoride	1.4	1.4	5.7	3.4
Iron (Total)	1.7	1.17	0.00	3.40
Iron (Dissolved)	--	0.00	0.00	2.62
Lead	<0.1	<0.1	0.4	0.6
Manganese	0.33	0.18	5.34	5.81
Mercury	<0.001	<0.001	<0.001	<0.001
Nickel	<0.1	<0.1	<0.1	<0.1
Selenium	<0.001	<0.001	0.001	<0.001
Silver	<0.5	<0.5	0.5	<0.05
Zinc	0.19	0.02	0.02	<0.02
Cyanide	<0.02	<0.02	<0.02	<0.02
MBAS	--	0.03	--	0.04
Phenol (ppm)	0.009	<0.001	0.015	0.012
Oil and Grease	0.0	0.0	2.3	2.5
Sulfides	0.0	<0.001	0.006	0.01

TABLE E-4

LITTLE THUNDER CREEK WATER QUALITY DATA

Water Quality Parameter (mg/l unless specified)	5-13-76	6-24-76	9-22-76	1-19-77
Calcium (Ca)	160	86	120	200
Magnesium (Mg)	100	41	110	100
Sodium (Na)	180	84	180	190
Potassium (K)	16	8.8	19	16
Total Cations (meq/l)	24.00	11.56	23.07	26.74
Carbonate (CO ₃)	30	0.0	0.0	0.0
Bicarbonate (HCO ₃)	280	210	280	410
Sulfate (SO ₄)	960	360	930	850
Chloride (Cl)	12	5.6	13	3.4
Nitrate (NO ₃)	0.2	0.7	0.0	0.3
Phosphate (PO ₄) as (P)	0.01	--	0.03	0.04
Fluoride (F)	0.9	0.6	0.9	1.1
Total Anions (meq/l)	25.98	11.22	24.41	24.56
Conductance (μmhos)	1930	981	2020	2040
COD	21	20	19	2.3
pH (SU)	8.6	8.0	8.1	8.0
Turbidity (NTU)	13	63	5	--
Hardness (CaCO ₃)	800	380	740	910
Silica (SiO ₂)	7.6	8.6	6.8	23
Nitrite	<0.1	<0.1	<0.1	<0.1
Sodium %	32	32	34	31
Total CO ₃	170	100	140	200
Ammonia (N)	0.0	0.0	0.0	0.0
Total Kjeldahl (N)	0.7	1.4	1.1	0.6
Suspended Solids	52	68	28	44
Vol. Suspended Solids	40	8.0	28	4
TDS	1660	738	1670	1630
Total Solids	1710	806	1700	1690

TABLE E-4 (Cont.)

Water Quality Parameter (mg/l unless specified)	5-13-76	6-24-76	9-22-76	1-19-77
Arsenic	<0.05	<0.05	<0.05	<0.05
Barium	<0.5	<0.5	<0.5	<0.5
Boron	0.32	0.14	0.32	2.4
Cadmium	<0.01	<0.01	<0.01	<0.01
Copper	<0.01	--	<0.01	<0.01
Chromium	<0.1	<0.1	<0.1	<0.1
Fluoride	0.9	0.6	0.9	1.1
Iron (Total)	0.07	0.63	0.00	0.10
Iron (Dissolved)	--	0.19	0.00	0.00
Lead	<0.1	<0.1	<0.1	0.3
Manganese	0.00	0.18	<0.05	1.28
Mercury	<0.001	<0.001	<0.001	<0.001
Nickel	<0.1	<0.1	<0.1	<0.1
Selenium	<0.001	<0.001	<0.001	<0.001
Silver	<0.5	<0.5	<0.5	<0.05
Zinc	0.40	<0.02	<0.02	<0.02
Cyanide	<0.02	<0.02	<0.02	<0.02
MBAS	--	<0.01	<0.01	0.02
Phenol (ppm)	<0.001	0.005	0.010	0.008
Oil and Grease	0.0	2.0	0.0	0.8
Sulfides	0.0	<0.001	<0.001	<0.001

TABLE E-5

MAXIMUM, MINIMUM, AND EXPECTED AVERAGE
WATER QUALITY VALUES FOR THE LITTLE POWDER RIVER

(Data for samples collected between April, 1976 and January, 1977)

Water Quality Parameter (mg/l unless specified)	Site 1			Site 2		
	Max.	Min.	Expected Range	Max.	Min.	Expected Range
Calcium (Ca)	340	76	50-350	320	54	50-350
Magnesium (Mg)	170	38	40-200	170	27	20-120
Sodium (Na)	770	130	100-800	772	120	120-700
Potassium (K)	42	9.1	10-15	42	8.1	10-20
Total Cations (meq/l)	52.17	12.71	--	44.17	10.42	--
Carbonate (CO ₃)	0.0	0.0	0.0	0.0	0.0	0.0
Bicarbonate (HCO ₃)	720	220	200-750	670	190	120-700
Sulfate (SO ₄)	1900	420	300-1600	1800	340	300-1600
Chloride (Cl)	14	2.9	10-50	33	7.4	10-30
Nitrate (NO ₃)	1.5	0.0	0-2.0	1.5	0.0	0.0-2.0
Phosphate (PO ₄) as (P)	0.14	0.02	<.10	0.14	0.02	<.10
Fluoride (F)	1.2	0.4	0-2.0	1.2	0.3	0-1.0
Total Anions (meq/l)	47.68	12.50	--	43.80	10.29	--
Conductance (umhos)	4040	1110	1000-4500	3780	970	900-3900
COD	27	14	10-50	27	13	20-30
pH (SU)	8.3	7.9	7.5-8.0	8.3	7.8	7.5-8.0
Turbidity (NTU)	315	6.5	5-400	380	14	10-400
Hardness (CaCO ₃)	1600	340	200-1200	1500	250	200-1200
Silica (SiO ₂)	13	4.8	3-20	14	2.4	3-20
Nitrite	<0.1	<0.01	<0.1	<0.1	<0.1	<0.1
Sodium %	64	25	--	73	29	--
Total CO ₃	350	110	100-400	330	91	100-400
Ammonia (N)	0.3	0.0	0.0	0.6	0.0	0.0
Total Kjeldahl (N)	1.8	0.6	0.5-3.0	2.1	0.7	0-4.0
Phosphate (PO ₄)	0.14	0.02	0-1.0	0.14	0.02	0-1.0
Suspended Solids	590	24	20-700	560	12	60-1100
Vol. Suspended Solids	50	8	5-60	50	6	5-60
TDS	3270	872	900-3000	3260	816	700-3500
Total Solids	3310	1460	1000-3500	3270	1380	1000-3500

TABLE E-5 (Cont.)

Water Quality Parameter (mg/l unless specified)	Site 1			Site 2		
	Max.	Min.	Expected Range	Max.	Min.	Expected Range
Arsenic	<0.05	<0.05	<0.007	<0.05	<0.05	<0.007
Barium	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Boron	3.2	0.14	0.1-4.0	3.97	0.12	<0.9
Cadmium	0.03	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	0.03	<0.01	<0.01	0.03	<0.01	<0.01
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron (Total)	2.86	0.00	0-7.0	4.22	0.00	0.5-5.0
Iron (Dissolved)	1.55	0.00	0-1.5	0.63	0.00	0-0.5
Lead	0.6	<0.1	<0.1	0.5	<0.1	<0.1
Manganese	0.59	<0.05	0-2.0	0.22	<0.05	0-2.0
Mercury	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	<0.5	<0.05	<0.5	<0.5	<0.05	<0.5
Zinc	0.03	<0.02	0-0.2	0.34	<0.02	0-0.5
Cyanide	<0.02	<0.02	<0.08	<0.02	<0.02	<0.008
MBAS	0.02	<0.01	0.0	<0.02	<0.01	0.0
Phenol (ppm)	0.006	<0.001	<0.002	0.006	<0.001	<0.01
Oil and Grease	1.7	1.1	0-3.0	1.6	0.4	0-2.0
Sulfides	0.002	0.0	0.0	<0.001	0.0	0.0

TABLE E-6

MAXIMUM, MINIMUM, AND EXPECTED AVERAGE
WATER QUALITY VALUES FOR ANTELOPE CREEK

(Data for samples collected between April, 1976 and January, 1977)

Water Quality Parameter (mg/l unless specified)	Site 1			Site 2		
	Max.	Min.	Expected Range	Max.	Min.	Expected Range
Calcium (Ca)	240	53	40-280	240	120	100-250
Magnesium (Mg)	100	38	25-100	110	46	25-150
Sodium (Na)	290	140	100-300	720	140	100-700
Potassium (K)	9.1	7.7	3-10	16	9.1	5-15
Total Cations (meq/l)	23.11	15.19	--	33.00	16.18	--
Carbonate (CO ₃)	0	0	0	0	0	0
Bicarbonate (HCO ₃)	370	180	150-400	670	170	200-700
Sulfate (SO ₄)	1200	480	350-1500	1600	560	450-1200
Chloride (Cl)	29	6.8	10-30	25	3.3	10-70
Nitrate (NO ₃)	0.5	0.0	0-1	1.2	0.2	<1.0
Fluoride (F)	1.3	0.7	0.2	1.1	0.8	<1.0
Total Anions (meq/l)	31.60	15.93	--	33.74	14.92	--
Conductance (μmhos)	2630	1440	1000-3000	3780	790	1000-4000
COD	16	3.2	10-50	16	12	10-25
pH (SU)	8.2	8.0	7.0-8.5	8.2	8.0	7.0-8.5
Turbidity (NTU)	6	1.3	5-180	450	2.5	5-400
Hardness (CaCO ₃)	1000	290	400-800	1000	490	500-1100
Silica (SiO ₂)	11	6.9	3-15	13	9.5	3-15
Nitrite	<0.1	<0.1	<0.1	<0.1	<0.1	<1.0
Sodium %	61	34	--	38	35	--
Total CO ₃	180	87	50-250	160	82	50-200
Ammonia (N)	0.6	0.0	0	0.0	0.0	0
Total Kjeldahl (N)	1.4	0.0	0-1.5	2.0	0.5	0.5-2.0
Phosphate (PO ₄)	0.05	0.01	<0.5	0.19	0.03	<1.0
Suspended Solids	28	8	10-150	1020	20	20-750
Vol. Suspended Solids	12	0.0	5-30	88	12	5-100
TDS	2200	992	800-2500	3060	996	900-3000
Total Solids	2230	1000	800-2500	2450	2020	1000-2800

TABLE E-6 (Cont.)

Water Quality Parameter (mg/l unless specified)	Site 1			Site 2		
	Max.	Min.	Expected Range	Max.	Min.	Expected Range
Arsenic	<0.05	<0.05	<0.01	<0.05	<0.05	<0.007
Barium	<0.05	<0.05	<0.5	<0.5	<0.5	<0.5
Boron	0.10	0.00	0-0.2	3.4	0.0	<0.5
Cadmium	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Copper	0.03	<0.01	<0.01	0.03	<0.01	<0.01
Chromium	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Iron (Total)	0.39	0.05	0-2.0	3.88	0.00	0.5-2.0
Iron (Dissolved)	0.15	0.00	0-1.0	1.60	0.00	0-0.5
Lead	0.2	<0.1	<0.1	0.5	<0.1	<0.1
Manganese	0.94	0.14	0-3	0.22	0.00	0-1.0
Mercury	<0.001	<0.001	<0.001	<0.0001	<0.001	0-0.007
Nickel	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Selenium	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Silver	<0.5	<0.05	<0.5	<0.5	<0.5	<0.5
Zinc	0.03	<0.02	<0.02	0.03	<0.02	<0.02
Cyanide	<0.02	<0.02	<0.008	<0.02	<0.02	<0.008
MBAS	0.02	<0.01	<0.01	0.02	<0.01	<0.01
Phenol (ppm)	0.002	<0.001	<0.001	0.005	<0.001	<0.002
Oil and Grease	2.4	0.0	0-2.0	1.4	0.0	0-3.0
Sulfides	0.01	<0.001	<0.001	<0.001	0.0	<0.001

TABLE E-7

MAXIMUM, MINIMUM, AND EXPECTED AVERAGE
WATER QUALITY VALUES FOR SCHOOL CREEK

(Data for samples collected between May, 1976 and January, 1977)

Water Quality Parameter (mg/l unless specified)	Max.	Min.	Expected Range
Calcium (Ca)	570	360	200-650
Magnesium (Mg)	660	210	175-700
Sodium (Na)	990	280	200-1200
Potassium (K)	82	17	10-100
Total Cations (meq/l)	127.79	48.60	
Carbonate (CO ₃)	28	0.0	0-20
Bicarbonate (HCO ₃)	880	520	200-1000
Sulfate (SO ₄)	5500	1800	1000-6000
Chloride (Cl)	91	4.3	4-100
Nitrate (NO ₃)	1.6	0.00	0-3.0
Phosphate (PO ₄) as (P)	0.17	0.01	0-1.0
Fluoride (F)	5.7	1.4	1.0-7.0
Total Anions (meq/l)	127.12	46.83	
Conductance (µmhos)	8290	3040	2000-9000
COD	170	62	20-250
pH (SU)	8.5	7.7	7.5-8.8
Turbidity (NTU)	19	2.3	0-250
Hardness (CaCO ₃)	4100	1800	1000-5000
Silica (SiO ₂)	16	2.7	2.0-20
Nitrite	<0.1	<0.1	<0.1
Sodium %	34	24	
Total CO ₃	2100	260	175-2500
Ammonia (N)	0.00	0.00	0.00
Total Kjeldahl (N)	6.6	1.1	0-10.0
Suspended Solids	128	20	0-800
Vol. Suspended Solids	36	8	0-50
TDS	9760	3160	1800-10,000
Total Solids	9770	3180	2000-10,000

TABLE E-7 (Cont.)

Water Quality Parameter (mg/l unless specified)	Max.	Min.	Expected Range
Arsenic	<0.05	<0.05	<0.05
Barium	<0.5	<0.5	<0.5
Boron	10	1.08	1.0-15
Cadmium	<0.01	<0.01	<0.01
Copper	<0.01	<0.01	<0.01
Chromium	<0.1	<0.1	<0.1
Fluoride	5.7	1.4	1.0-7.0
Iron (Total)	3.40	0.00	0-4.0
Iron (Dissolved)	2.62	0.00	0-3.0
Lead	0.6	<0.1	<1.0
Manganese	5.81	0.18	0-8.0
Mercury	<0.001	<0.001	<0.001
Nickel	<0.1	<0.1	<0.1
Selenium	<0.001	<0.001	<0.001
Silver	0.5	<0.05	<1.0
Zinc	0.19	<0.02	<1.0
Cyanide	<0.02	<0.02	<0.02
MBAS	0.04	0.03	<0.10
Phenol (ppm)	0.015	<0.001	<0.10
Oil and Grease	2.5	0.0	0-5
Sulfides	0.01	0.0	0.0

TABLE E-8

MAXIMUM, MINIMUM, AND EXPECTED AVERAGE
WATER QUALITY VALUES FOR LITTLE THUNDER CREEK

(Data for samples collected between May, 1976 and January, 1977)

Water Quality Parameter (mg/l unless specified)	Max.	Min.	Expected Range
Calcium (Ca)	200	86	40-250
Magnesium (Mg)	110	41	25-150
Sodium (Na)	190	84	75-200
Potassium (K)	19	8.8	7-25
Total Cations (meq/l)	26.74	11.56	
Carbonate (CO ₃)	30	0.0	0-20
Bicarbonate (HCO ₃)	410	210	175-500
Sulfate (SO ₄)	960	360	200-1200
Chloride (Cl)	13	3.4	2.5-15
Nitrate (NO ₃)	0.7	0.0	0-2.0
Phosphate (PO ₄) as (P)	0.04	0.01	<.10
Fluoride (F)	1.1	0.6	0-1.5
Total Anions (meq/l)	25.98	11.22	
Conductance (µmhos)	2040	981	700-2500
COD	21	2.3	5-25
pH (SU)	8.6	8.0	7.5-8.8
Turbidity (NTU)	63	5	10-250
Hardness (CaCO ₃)	910	380	250-1000
Silica (SiO ₂)	23	6.8	5-25
Nitrite	<0.1	<0.1	<0.1
Sodium %	34	31	
Total CO ₃	200	100	80-300
Ammonia (N)	0.00	0.00	0.0
Total Kjeldahl (N)	1.4	0.6	0-2.5
Suspended Solids	68	28	10-200
Vol. Suspended Solids	40	4	2-75
TDS	1670	738	600-2500
Total Solids	1710	806	600-2500

TABLE E-8 (Cont.)

Water Quality Parameter (mg/l unless specified)	Max.	Min.	Expected Range
Arsenic	<0.05	<0.05	<0.05
Barium	<0.5	<0.5	<0.5
Boron	2.4	0.14	0-4.0
Cadmium	<0.01	<0.01	<0.01
Copper	<0.01	<0.01	<0.01
Chromium	<0.1	<0.1	<0.1
Fluoride	1.1	0.6	0-2.0
Iron (Total)	0.63	0.00	0-2.0
Iron (Dissolved)	0.19	0.00	0-1.0
Lead	0.3	<0.1	0-1.0
Manganese	1.28	0.00	0-2.5
Mercury	<0.001	<0.001	<0.001
Nickel	<0.1	<0.1	<0.1
Selenium	<0.001	<0.001	<0.001
Silver	<0.5	<0.05	<0.05
Zinc	0.40	<0.02	0-1.0
Cyanide	<0.02	<0.02	<0.02
MBAS	0.02	<0.01	<0.01
Phenol (ppm)	0.010	<0.001	<0.01
Oil and Grease	2.0	0.0	0-3.0
Sulfides	<0.001	0.0	<0.001

Appendix F

EPA WATER QUALITY CRITERIA
AND WYOMING WATER QUALITY STANDARDS

TABLE F-1

E.P.A. - WATER QUALITY CRITERIA USED FOR ASSESSMENT

	AQUATIC LIFE	RECREATION AND BODY CONTACT	RAW WATER SUPPLY	AGRICULTURE
Dissolved solids			250mg/L for chlorides & sulfates	1500mg/L
Dissolved oxygen	5.0mg/L or more (1)			
Turbidity (SUSP, Solids)				
pH	6.5-9.0		5-9.0	6.0-9.0
Ammonia (un-ionized)	0.020mg/L (2)			
Nitrates; nitrites			10mg/L	
Arsenic			50µg/L	100µg/L
Cyanide	5.0µg/L			
Chlorine	2.0µg/L - for Salmonid fish. 10.0µg/L for other organisms.			
SAR				15
Chloride	-----See Dissolved Solids-----			
Sulfate	-----See Dissolved Solids-----			
Fluoride				
Boron				750µg/L
Cadmium	(3)		10µg/L	0.01mg/L
Chromium	100µg/L		50µg/L (4)	0.5mg/L
Cobalt				
Copper	0.1 x (5)		1.0mg/L	1.0mg/L
Iron	1.0mg/L		0.3mg/L	
Lead	0.01 x (6)		50µg/L	5.0mg/L
Manganese			50µg/L	2.0mg/L
Mercury	0.05µg/L		2.0µg/L	
Silver	0.01 x (7)		50µg/L	
Zinc	0.01 x (7)		5000µg/L	5.0mg/L
Selenium	0.01 x (7)		10µg/L	0.05mg/L
Fecal coliform		200 per 100 ml (8)		
Alkalinity (CaCO ₃)	20mg/L or more			

FOOTNOTES

- (1) For DO safe levels see Tables 1.0 and 1.1
- (2) Criterion is a function of pH and temperature which control un-ionized ammonia (toxic to aquatic life).
See Table 1.2
- (3) For aquatic life criterion see Table 1.3
- (4) This may be too high as only the hexavalent form is thought to be harmful to man.
- (5) A 96-hour LC_{50} as determined through non-aerated bioassay using a sensitive aquatic resident species.
- (6) The 96-hour LC_{50} value, using the receiving or comparable water as the diluent and soluble lead measurements (non-filterable lead using an 0.45 micron filter), for sensitive freshwater resident species.
- (7) The 96-hour LC_{50} as determined through bioassay using a sensitive resident species.
- (8) Based on a minimum of not less than five samples taken over a 30-day period, the fecal coliform bacterial level should not exceed a log mean of 200 per 100 ml, nor should more than 10 percent of the total samples taken during any 30-day period exceed 400 per 100 ml.

TABLE F-2

FISH AND OTHER AQUATIC LIFE (FRESH AND MARINE WATERS)

Estimated Natural
Seasonal Minimum
Concentration of
Oxygen in Water

Recommended Minimum Concentrations of
Dissolved Oxygen for Selected Levels of Protection

	Nearly Maximal	High	Moderate	Low
5	5	4.7	4.2	4.0
6	6	5.6	4.8	4.0
7	7	6.4	5.3	4.0
8	8	7.1	5.8	4.3
9	9	7.7	6.2	4.5
10	10	8.2	6.5	4.6
12	12	8.9	6.8	4.8
14	14	9.3	6.8	4.9

Source: Environmental Protection Agency, "Quality Criteria For Water", October, 1975.

TABLE F-3

GUIDELINES FOR SELECTING DESIRED TYPE AND
LEVEL OF PROTECTION OF FISH AGAINST DELETERIOUS EFFECTS OF
REDUCED OXYGEN CONCENTRATIONS

Level of Protection	Intended Type of Protection	Possible Application
Nearly Maximal	For virtually unimpaired productivity and unchanged quality of a fishery.	Appropriate for conservation areas, parks, and water bodies of high or unique value. Requires, practically speaking, that little or no de-oxygenating wastes be added to natural waters. Nor must there be any activities such as unfavorable land use which would reduce O_2 levels.
High	Not likely to cause appreciable change in the ecosystem, nor material reduction in fish production. Some impairment is risked, but appreciable damage is not to be expected at these levels of oxygen.	Could be appropriate for fisheries or aquatic ecosystems of some importance which should not be impaired by other uses of water.
Moderate	Fisheries should persist, usually with no serious impairment, but with some decrease in production.	Could be used for fisheries which are valued. but must co-exist with major industries or dense human population.
Low	Should permit the persistence of sizeable populations of tolerant species and successful passage of most migrants. Much reduced production or elimination of sensitive fish is likely.	Appropriate for fisheries that have some commercial or recreational value, but are so unimportant compared with other water uses, that their maintenance cannot be a major objective of pollution control. This type of protection should, however, provide for survival of sensitive species in adult or subadult like stages for short periods during the year, of oxygen levels at other times are satisfactory for growth, reproduction, etc.

Source: Environmental Protection Agency
"Quality Criteria for Water", October 1975.

TABLE F-4

CONCENTRATIONS OF TOTAL AMMONIA ($\text{NH}_3 + \text{NH}_4^+$) WHICH CONTAIN
AN UN-IONIZED AMMONIA CONCENTRATION OF 0.020 MG/L NH_3 *

Temperature (°C)	pH Value								
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	160	51	16	5.1	1.6	0.53	0.18	0.071	0.036
10	110	34	11	3.4	1.1	0.36	0.13	0.054	0.031
15	73	23	7.3	2.3	0.75	0.25	0.093	0.043	0.027
20	50	16	5.1	1.6	0.52	0.18	0.070	0.036	0.025
25	35	11	3.5	1.1	0.37	0.13	0.055	0.031	0.024
30	25	7.9	2.5	0.81	0.27	0.099	0.045	0.028	0.022

*Abstracted from Thurston et al. 1974

TABLE F-5

CADMIUM CRITERION FOR AQUATIC LIFE

FRESH WATER

<u>SOFT WATER*</u>	<u>HARD WATER*</u>	
0.4 mg/L	1.2 mg/L	For cladocerans and salmonid fishes;
4.0 mg/L	12.0 mg/L	For other, less sensitive, aquatic life.

*Classification of water by hardness content

<u>Concentration mg/L CaCO₃</u>	<u>Description</u>
0 - 75	Soft
75-150	Moderately hard
150-300	Hard
300 and up	Very hard

TABLE F-6

PROPOSED WYOMING WATER QUALITY STANDARDS - 1977

	CLASS I* WATERS	CLASS II* WATERS	CLASS III* WATERS
Dissolved oxygen	6mg/L or more	5mg/L or more	
pH	6.0 - 9.0	6.0 - 9.0	6.0 - 9.0
Fecal coliform (1)	200 per 100 ml	200 per 100 ml	200 per 100 ml
Oil and grease	10mg/L	10mg/L	10mg/L
Dissolved solids			
Radioactive material	5pCi/L of total radium 226 plus radium 228.	5pCi/L of total radium 226 plus radium 228.	5pCi/L of total radium 226 plus radium 228.
	8pCi/L of total strontium 90	8pCi/L of total strontium 90	8pCi/L of total strontium 90
Un-ionized ammonia (As N) (2)	0.02mg/L	0.02mg/L	
Chlorine (3)	0.002mg/L	0.01mg/L	
Turbidity	10 NTU's (4) increase	15 NTU's (4) increase	
Total dissolved gases	110% of saturation value	110% of saturation value	

FOOTNOTES

(1) Section 25. Coliform Bacteria

- a. All still surface water bodies which lie at an elevation of less than 7,000 feet above sea level shall be considered suitable for full body contact recreation and the following limits shall apply:

During the recreation season (May 1 through September 30) wastes shall not be discharged in amounts which will cause fecal coliform concentrations to exceed a geometric mean of 200 fecal coliform groups per 100 milliliters, based on a minimum of not less than 5 samples obtained during separate 24-hour periods for any 30-day period, nor shall ten percent of the samples exceed 400 groups per 100 milliliters during any 30-day period.

- b. In all Class III water the following limits shall apply:

During the entire year wastes shall not be discharged in amounts which will cause fecal coliform concentrations to exceed a geometric mean of 200 fecal coliform groups per 100 milliliters, based on a minimum of not less than 5 samples obtained during separate 24-hour periods for any 30-day period, nor shall ten percent of the samples exceed 400 groups per 100 milliliters during any 30-day period.

- c. All surface waters not described in sections a or b of this Section shall be considered suitable for secondary body contact recreation and the following limits shall apply:

During the recreation season (May 1 through September 30) fecal coliform concentrations shall not exceed a geometric mean of 1,000 fecal coliform groups per 100 milliliters, based

on a minimum of not less than 5 samples obtained during separate 24-hour periods for any 30-day period, nor shall 10 percent of the samples exceed 2,000 groups per 100 milliliters during any 30-day period.

- (2) pH and temperature control un-ionized ammonia which is toxic to aquatic life. See Table 1.0.
- (3) Chlorine - In those Class I waters designated as cold water fisheries the total residual chlorine concentration shall not exceed .002 mg/l. In those Class I waters designated as warm waters the total residual chlorine content shall not exceed .01 mg/l.
- (4) NTU - Nephelometric Turbidity Unit.

TABLE F-7

CONCENTRATIONS OF TOTAL AMMONIA ($\text{NH}_3 + \text{NH}_4^+$) WHICH CONTAIN
AN UN-IONIZED AMMONIA CONCENTRATION OF 0.020 mg/L NH_3 *

Temperature (°C)	pH Value								
	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
5	160	51	16	5.1	1.6	0.53	0.18	0.071	0.036
10	110	34	11	3.4	1.1	0.36	0.13	0.054	0.031
15	73	23	7.3	2.3	0.75	0.25	0.093	0.043	0.027
20	50	16	5.1	1.6	0.52	0.18	0.070	0.036	0.025
25	35	11	3.5	1.1	0.37	0.13	0.055	0.031	0.024
30	25	7.9	2.5	0.81	0.27	0.099	0.045	0.028	0.022

* Abstracted from Thurston et al. 1974

* Classification of Wyoming Waters:

Class I. Those waters which, based on information supplied by the Wyoming Game and Fish Department, are determined to be presently supporting game fish or have the hydrologic and natural water quality potential to support game fish.

Class II. Those waters which, based on information supplied by the Wyoming Game and Fish Department, are determined to be presently supporting non-game fish or have the hydrologic and natural water quality potential to support non-game fish.

Class III. Those waters which, based on information supplied by the Wyoming Game and Fish Department, are determined as not having the hydrologic or natural water quality potential to support fish.

TABLE F-8

WYOMING WATER QUALITY STANDARDS - 1974

	CLASS I* WATERS	CLASS II* WATERS	CLASS III* WATERS
Dissolved oxygen	6mg/L or more	5mg/L or more	
pH	6.5-8.5	6.5-8.5	6.5-8.5
Fecal coliform (1)	200 per 100 ml	200 per 100 ml	200 per 100 ml
Oil and grease	10mg/L	10mg/L	10mg/L
Dissolved solids			
Radioactive material	3pCi/L of radium 226	3pCi/L of Radium 226	3pCi/L of Radium 226
	10pCi/L of strontium 90	10pCi/L of strontium 90	10pCi/L of strontium 90
Turbidity	10 JTU (2) increase	10 JTU (2) increase	
TOTAL GAS PRESSURE	-----110% of Existing Atmospheric Pressure-----		

FOOTNOTES

(1) Section 25. Coliform Bacteria. For still water bodies which lie at an altitude of less than 7,000 feet above sea level, the following limits shall apply:

a. During the recreation season (May 1 through September 30), wastes of other than natural origin shall not be discharged in amounts which will cause fecal coliform concentrations to exceed a geometric mean of 200 fecal coliform groups per 100 milliliters, based on a minimum of not less than five samples obtained during separate 24-hour periods for any 30-day period, nor shall ten percent of the samples exceed 400 groups per 100 milliliters during any 30-day period.

In addition, the above standard will also apply to the following streams:

- 1) The North Platte River starting at the Colorado-Wyoming state line and extending downstream to the outlet of Alcova Reservoir, and including tributaries, the Encampment River and Big Creek.
- 2) The Tongue River from the intake of the Ranchester Municipal Water Treatment Plant upstream to the headwaters.
- 3) The Green River commencing with the waters of Flaming Gorge Reservoir at the Wyoming-Utah state line, upstream to its headwaters.
- 4) The Snake River commencing at the Wyoming-Idaho state line, upstream to the south boundary of Yellowstone Park.

For all other waters the following limits shall apply:

b. During the recreation season (May 1 through September 30), fecal coliform concentrations shall not exceed a geometric mean of 1,000 fecal coliform groups per 100 milliliters, based on a minimum of not less than five samples obtained during separate 24-hour periods for any 30-day period, nor shall ten percent of the samples exceed 2,000 groups per 100 milliliters during any 30-day period.

(2) Jackson Turbidity Units

* Classification of Wyoming Waters:

Class I. Those waters which, based on information supplied by the Wyoming Game and Fish Department, are determined to be presently supporting game fish or have the hydrologic and natural water quality potential to support game fish.

Class II. Those waters which, based on information supplied by the Wyoming Game and Fish Department, are determined to be presently supporting non-game fish or have the hydrologic and natural water quality potential to support non-game fish.

Class III. Those waters which, based on information supplied by the Wyoming Game and Fish Department, are determined as not having the hydrologic or natural water quality potential to support fish.